



"The Global Power Company"

February 11, 2000

Mr. William Grimley
Emission Measurement Center (MD-19)
United States Environmental Protection Agency
Research Triangle Park, NC 27711
Attn: Electric Utility Steam Generating Unit Mercury Test Program

Re: Duck Creek Power Plant
Mercury ICR Phase III

Dear Mr. Grimley:

The United States Environmental Protection Agency (EPA) has undertaken an Information Collection Request (ICR) pursuant to its efforts in assessing emissions from coal fired power plants. This ICR was initiated through EPA's authority under section 114 of the Clean Air Act. Specifically, EPA selected Central Illinois Light Company's (CILCO) Duck Creek facility near Canton, Illinois to perform speciated mercury emissions and related testing in 1999. The focus of this testing was to characterize emissions at this unit and to assess the effectiveness of the installed pollution controls on such emissions.

The Duck Creek facility was tested under essentially the same protocol and with essentially the same focus in 1998. In accordance with EPA's letter of March 11, 1999 which put forth the requirements for such testing, CILCO proposed to utilize the 1998 test data to fulfill it's ICR Phase III obligations. After conferring with you, Mr. William Maxwell, and Ms. Lara Autry at EPA, as well as Mr. Matt DeVito at CONSOL R&D Inc., CILCO determined that use of the 1998 test data was a viable approach. CONSOL R&D, Inc. was then retained by CILCO to prepare the required documents and final test report consistent with EPA's ICR.

Enclosed is the final test report "Speciated Mercury Emission Measurements From Central Illinois Light Company Duck Creek Station" dated January 31, 2000 as prepared by CONSOL R&D, Inc. This report presents the findings of the testing conducted at the Duck Creek facility during 1998. Deviations to the EPA prescribed test plan are noted in the report. These deviations were discussed with EPA and are not believed to have an effect on the test objectives or results. Also enclosed are copies of the EPA correspondence pertinent to this testing and reporting.

CILCO appreciates the opportunity to work with EPA on this project and in particular appreciates the flexibility to utilize earlier test data to meet our mutual objectives. Please feel free to contact me if you have any questions. My phone number is 309-633-2861 and email is bobbisha@cilco.com.

Sincerely,

A handwritten signature in black ink that reads "Robert M. Bisha". The signature is written in a cursive, flowing style.

Robert M. Bisha

cc: Rob Somogyi
Dave Tomlinson
James Luckey
Dave Kolaz – Illinois EPA
Bharat Mathur – USEPA Region V
William Maxwell – USEPA RTP

Speciated Mercury Emission Measurements From Central Illinois Light Company Duck Creek Station

Prepared for:

**Central Illinois Light Company (CILCO)
300 Liberty Station
Peoria, Illinois 61602**

CILCO Project Manager:

**Robert Bisha
309-633-2861**

Prepared by:

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CONSOL Program Manager

**Matthew DeVito
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Report Date: January 31, 2000



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January 31, 2000

412-854-6679

Mr. Robert Bisha
Central Illinois Light Company
AES Edwards Power Plant
7800 South CILCO Lane
Bartenville, IL 61607

Re: CILCO Duck Creek Station Mercury Emission Report for EPA ICR

Dear Mr. Bisha:

Attached are four copies of the Duck Creek Station Mercury (Hg) Emission Report prepared by CONSOL R&D for submission to the U.S. EPA in compliance with the EPA Mercury Information Collection Request. This report complies with the EPA format specifications. The report and Hg emissions data were reviewed by me and CONSOL R&D management. To the best of my knowledge, the data contained in this report are accurate and represent the Hg emissions and control for the operating conditions maintained during the test period.

CONSOL Energy Inc. is committed to finding solutions to environmental issues and sustaining Illinois coal as a viable fuel option. We were glad to be of assistance for this program and look forward to future opportunities to develop cooperative efforts that are mutually beneficial. Please address any questions or comments regarding this work and potential future work to me. Thank you.

Sincerely,

M. S. DeVito
Research Group Leader

/ls

cc: F. P. Burke
R. M. Statnick

Speciated Mercury Emission Measurements From Central Illinois Light Company Duck Creek Station

Prepared for:

**Central Illinois Light Company (CILCO)
300 Liberty Station
Peoria, Illinois 61602**

CILCO Project Manager:

**Robert Bisha
309-633-2861**

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LIST OF ABBREVIATIONS

ΔH	-	Meter Orifice Flow Factor
AES	-	Atomic Emission Spectroscopy
ASTM	-	American Society for Testing and Materials
Avg	-	Average
Bar.	-	Barometric
Btu	-	British Thermal Unit (Fuel Heating Value)
CaSO_3	-	Calcium Sulfite
CEM	-	Continuous Emission Monitoring System
CFM	-	Cubic Feet Per Minute
CILCO	-	Central Illinois Light Company
Cl	-	Chlorine
CO_2	-	Carbon Dioxide
Conc.	-	Concentration
CVAA	-	Cold Vapor Atomic Absorption
DI	-	De-ionized Water
DOE	-	United States Department of Energy
dscf	-	Dry Standard Cubic Feet (at 68 °F and 29.92 " Hg)
dscfm	-	Dry Standard Cubic Feet Per Minute
dscm	-	Dry Standard Cubic Meter
dscmm	-	Dry Standard Cubic Meters Per Minute
Econ.	-	Economizer
EERC	-	Energy and Environmental Research Center
Eff.	-	Efficiency
ESP	-	Electrostatic Precipitator
F-Factor	-	Fuel Factor (dscf gas produce per MM Btu fuel Fired)
FGD	-	Flue Gas De-Sulfurization
fps	-	Feet Per Second
ft^2	-	Square Feet
g	-	Gram
h	-	Hour
H_2O	-	Water or Moisture
H_2O_2	-	Hydrogen Peroxide
HCl	-	Hydrogen Chloride (Hydrochloric Acid)
HF	-	Hydrogen Fluoride
Hg	-	Mercury
HNO_3	-	Nitric Acid
ICCI	-	Illinois Clean Coal Institute
ICP	-	Inductively Coupled Plasma
ICR	-	Information Collection Request (for utility Hg emissions)
IR	-	Infrared
ISGS	-	Illinois State Geological Survey
KCl	-	Potassium Chloride
KMnO_4	-	Potassium Permanganate
lb	-	Pound
m^3	-	Cubic Meter

LIST OF ABBREVIATIONS (continued)

mg	-	Milligram
min	-	Minute
mL	-	Milliliter
KMnO ₄	-	Potassium Permanganate
lb	-	Pound
m ³	-	Cubic Meter
mg	-	Milligram
min	-	Minute
mL	-	Milliliter
MM	-	Million
MWe	-	Megawatts of Utility Electrical Load
N	-	Normality (solution strength)
ng	-	Nanogram
NIST	-	National Institute of Standards and Technology
NO _x	-	Gaseous Oxides of Nitrogen
O ₂	-	Oxygen
OCDO	-	Ohio Coal Development Office
OH	-	Ontario Hydro Sampling Train
ppb	-	Parts Per Billion
ppm	-	Parts Per Million
ppmv	-	Parts Per Million by Volume
Pres.	-	Pressure
psig	-	Pounds per square inch gauge pressure
QA	-	Quality Assurance
QC	-	Quality Control
RPD	-	Relative Percent Difference
sec	-	Seconds
SO ₂	-	Sulfur Dioxide
SO _x	-	Gaseous Sulfur Oxide Compounds
SRM	-	Standard Reference Material
std. dev.	-	Standard Deviation
tph	-	Tons Per Hour
tpy	-	Tons Per Year
U.S. EPA-	-	United States Department of Environmental Protection
Y	-	Meter Volume Calibration Factor
°C	-	Temperature in Degrees Celsius
°F	-	Temperature in Degrees Fahrenheit
µg	-	Microgram

1.0 INTRODUCTION

1.1 Summary of Test Program

The U.S. Environmental Protection Agency (EPA) has undertaken a program to acquire additional information related to emissions of mercury (Hg) from electric utility steam generating stations. As part of this program, EPA is gathering information regarding the Hg concentration in the utility coal supply and flue gas emission data from selected sources. The Central Illinois Light Company (CILCO) Duck Creek Power Plant was selected by EPA for flue gas Hg testing to characterize speciated mercury emissions and the effectiveness of the control measures in place at this facility.

The Duck Creek Power Plant, located at 17751 N. CILCO Road, Canton, IL (61520-8761), was randomly selected from a group of utilities that are representative of units operating on bituminous coal and incorporating a cold-side electrostatic precipitator (ESP) for particulate control and a wet scrubber for SO₂ control.

The CONSOL Inc. Research & Development Department completed a mercury emission evaluation program at Duck Creek Station in July 1998. The objective of this testing was to determine the Hg speciation at the inlet and outlet of the wet scrubber and the Hg removal across the wet scrubber and the emission control ESP system. Although this testing was conducted in July 1998, the sampling procedures and strategy employed were very similar to the procedures prescribed in the EPA Mercury Information Collection Request (ICR). Therefore, the host utility, Central Illinois Light Company, petitioned EPA to use the pre-existing data in place of additional Hg emission testing. These data are sufficient to meet the EPA ICR objectives.

The field sampling and associated laboratory analyses were completed by personnel from CONSOL Inc. Research and Development Department (CONSOL R&D). The work was co-funded by CONSOL Inc., the Illinois Clean Coal Institute (ICCI), the Illinois State Geological Survey (ISGS), and the U.S. Department of Energy - Federal Energy Technology Center.

The Duck Creek Power Plant is a pulverized coal wall-fired boiler. The plant is equipped with a three-field ESP for particulate control and a natural oxidation wet flue gas scrubber for SO₂ control. Flue gas Hg measurements were conducted at the ESP inlet and scrubber outlet to determine the flue gas Hg concentration at both locations, the speciation of Hg at both locations, and the Hg removal across the scrubber. In addition, process stream samples (coal, bottom ash, economizer ash, ESP ash, and FGD slurry) were obtained to determine the fate of Hg within the emission control system and for material balance calculations. In addition to the Hg measurements, flue gas HCl and HF measurements were obtained at both the ESP inlet and scrubber outlet. The test program was conducted for three consecutive days from July 14 to July 16, 1998.

1.2 Key Personnel

The key personnel who coordinated this test program and their phone numbers are:

- | | | |
|-------------------------------|--------------------|----------------|
| • Plant Environmental Officer | - Robert Bisha | - 309-633-2861 |
| • Plant Contact | - Chuck Wier* | - 309-668-3803 |
| • CONSOL Program Manager | - Matthew DeVito | - 412-854-6679 |
| • CONSOL Team Leader | - Ron Oda | - 412-854-6539 |
| • CONSOL Lab Supervisor | - Dr. Vince Conrad | - 412-854-6509 |
| • ICCI Program Manager | - Dr. Ron Carty | - 618-985-3500 |
| • DOE Program Manager | - Tom Brown | - 412-892-4691 |

* Mr. Wier has retired and is replaced by Dave Tomlinson.

2.0 PLANT AND SAMPLING LOCATION DESCRIPTIONS

This program was conducted in July, 1998 and was designed to meet a number of objectives in addition to flue gas Hg speciation measurements and Hg removal across the wet scrubber. Because of this, a number of additional process stream samples were obtained. The samples obtained for this program are summarized in the following table.

TABLE 1. DUCK CREEK SAMPLING LOCATIONS

Sample Stream	ID
ESP Gas Inlet	A-1
FGD Gas Outlet	A-2
Coal to Mills	S-1
Bottom Ash	S-2
Economizer Ash	S-3
ESP Ash - 1 st Field	S-4
ESP Ash - 2 nd Field	S-5
ESP Ash - 3 rd Field	S-6
Limestone	S-7
Make-Up Water	L-1
FGD Slurry	L-2
FGD Filtrate	L-3
FGD Solids	S-8

2.1 Process Description and Operation

The Duck Creek Power Plant is a 400 MWe pulverized coal-fired utility system. Bituminous coal from the Freeman United Crown II Mine (Macoupin County, Illinois) is delivered by rail to the storage stockpile. Coal is conveyed from the stockpile to the day storage bunkers. These bunkers feed the three Riley mills that pulverize the coal to ~70% minus 200 mesh. The mills supply the pulverized coal to the rows of burners located on the boiler front wall. The coal is combusted in a front wall-fired Riley boiler, and the heat generated is used in the production of superheated steam (3,000,000 lb/h) which is expended in a steam turbine to generate electricity. Mineral matter inherent in the coal matrix does not burn and forms a solid residue stream referred to as ash. Part of the ash remains in the boiler and is removed in the form of bottom ash. The remainder of the ash is entrained in the flue gas and is conveyed out of the boiler with as fly ash. After exiting the superheater and economizer sections, the flue gas passes thorough an economizer particulate knock-out device in which a small percentage of the fly ash is removed and collected in the economizer hoppers (<2%). The economizer hopper ash particles are removed by gravity separation and, thus, are relatively large in particle size compared to the ESP ash. The flue gas then passes through an air preheater (heat exchange device), which increases the temperature of the combustion air while lowering the temperature of the flue gas from ~700 °F to ~300 °F. From the air preheater, the gas is conveyed to a three-field ESP, which removes greater than 99.8% of the remaining fly ash. Most of the fly ash is removed in the first field. The nearly particulate-free flue gas exits the ESP and enters the FGD system. The Riley venturi scrubber consists of four absorber modules. The gas is contacted with a limestone slurry, which removes ~80-86% of the SO₂. The slurry collects in the scrubber hold tank and is recycled to the scrubber module; a small percentage (scrubber blowdown) is sent to a thickener for de-watering and solids coagulation. The flue gas exits the scrubber and is conveyed to the stack. A detailed schematic of the process flow and sampling locations is shown in Figure 1.

The plant burns ~1,000,000 ton/year (tpy) of coal and produces ~68,000 tpy of fly ash, ~10,500 tpy of bottom ash, and ~141,000 tpy of FGD sludge. Recent operating history show this plant operating at an ~68% capacity factor. The scrubber is designed for an SO₂ removal efficiency of 86% with the plant firing a 3.4% sulfur coal. Limestone usage is ~90,000 tpy.

A detailed listing of plant equipment and specification is provided below:

Three Riley Stoker Ball Tube Mills

- pulverized coal at 70% minus 200 mesh.

Riley Stoker Steam Generating Unit

- Constructed in 1973
- 400 MW
- 3,000,000 lb/hr steam @2600 psig and 1005 °F

Pollution Control Walther Model 2P 2C 32D 3F/12 X 40 X 43.2 electrostatic precipitator

- | | |
|--------------------------------------|--------------------------------------|
| - 1,520,000 ACFM gas volume @ 275 °F | - 4.95 ft/sec gas velocity |
| - 99.8% design collection efficiency | - 8.73 sec particle residence time |
| - 128 gas passages | - 442,368 ft ² plate area |
| - 12" gas passage width | - 291 SCA |
| - 40' collection plate height | - 10.8 "W" cm/sec |
| - 43.2' treatment length | - 12 electrical sets |
| - 1.08 aspect ratio | - 3 x 14.4' fields in series |

Riley Enviroengineering Venturi-Sorber Scrubber / 4 modules

- | | |
|---|-----------------------------------|
| - Model A5300 | - 1" O.D. rod beds |
| - 2 banks of Chevron mist eliminators | - 4" ceramic slurry spray nozzles |
| - 342,625 ACFM @ 275°F inlet gas flow | - 45,600 lb/hr slurry feed |
| - 300,962 ACFM @ 127 °F outlet gas flow | - 885 GPM demister spray |

Manufacturer and Model of CEM Instrumentation

- Western Research Model 721M SO₂ Analyzer
- Rosemount Model OXA 1000 O₂ Analyzer
- Thermo Environmental Model 42C NO_x Analyzer
- Lear-Siegler Model RM41 Opacity Monitor
- United Sciences Inc., Model 100 Flow Monitor System

Three mercury material balance tests were conducted at Duck Creek Station. Each test period included simultaneous flue gas sampling at the ESP inlet and at FGD outlet. Samples were obtained using the Ontario Hydro (OH train) Hg speciation method (Draft Method ca. May 1998). The OH train is capable of speciating Hg into three fractions; 1) Hg adsorbed on particulate, 2) oxidized Hg, and 3) elemental Hg. Acid gas (HCl and HF) sampling also was conducted at the ESP inlet and FGD outlet. In addition to flue gas samples, representative process stream samples were obtained during the test period. Process stream samples included: coal, ash (bottom, economizer, ESP ash from each field), limestone, scrubber make-up water, scrubber by-product (sludge), and scrubber discharge water. The samples were analyzed for mercury, and the results were used to calculate material balances. The sampling locations are presented in Figures 1.

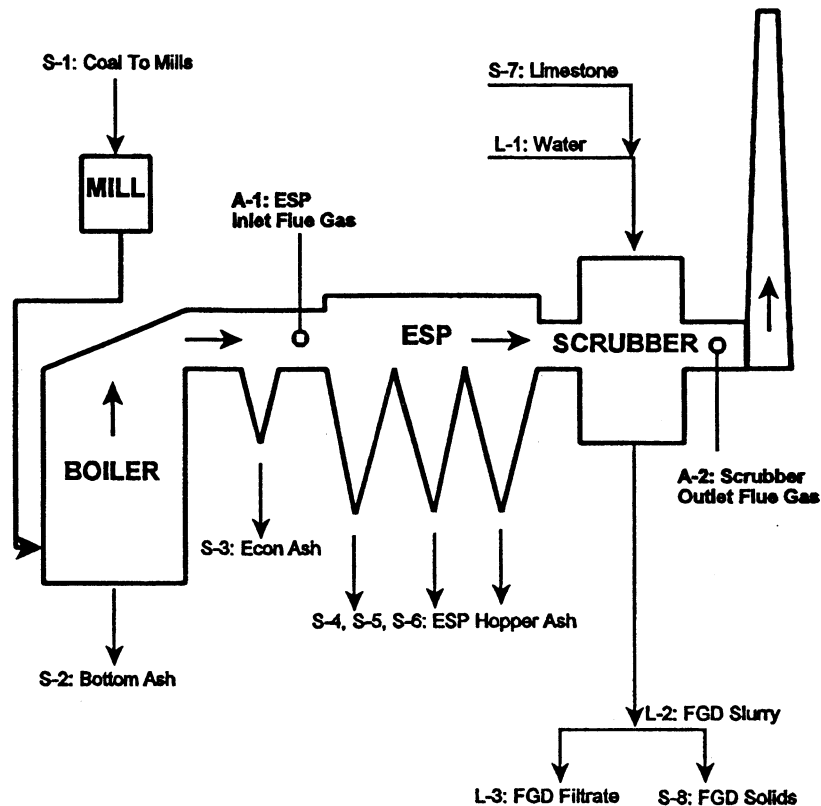


Figure 1. Duck Creek Station Schematic - Process Flow & Sampling Locations

During the test periods, pertinent boiler and scrubber operating data were obtained periodically to ensure steady-state plant operation. The control room staff provided complete logs of boiler and scrubber operating data for the test periods.

2.1.1- Boiler/Scrubber Operation

The Duck Creek Station can generate 400 MWe. Typically, the plant is operated in load following conditions. This results in ~16 hours at 330-380 MWe and ~8 hours at 250-300 MWe. One objective of the test program was to determine the accuracy and reliability of existing mercury-in-flue-gas measurement techniques. This required repetitive measurements taken under similar conditions. The operating staff was asked to maintain similar boiler and scrubber operating conditions for each test period. The operating parameters maintained at Duck Creek Station during the test periods are presented in the following table.

TABLE 2. BOILER/SCRUBBER OPERATING PARAMETERS

Plant Parameter	Test 1	Test 2	Test 3	Average
Megawatts	374	375	375	375
Coal Feed, lb/hr (dry)	311,700	315,700	305,300	310,900
%O ₂ @ Economizer	2.5	2.2	2.6	2.4
Stack Flue Gas Parameters				
Flow, dscfm	869,600	875,300	853,400	866,100
%O ₂	5.4	5.3	5.5	6.0
%CO ₂	12.8	14.6	14.4	13.9
NO _x , ppmv ¹	387	373	381	380
SO ₂ , ppmv ¹	540	500	535	524
SO ₂ , lb/h	4674	4373	4563	4537
Scrubber Parameters				
Limestone Use, tph	~16	~16	~16	~16
FGD Slurry % Solids	13.1	13.5	13.0	13.2
Absorber Slurry pH	5.8	5.8	5.8	5.8
SO ₂ Removal, %	82	83	82	82

1- Obtained from plant CEM system

For the test program, the plant was operating at 375 megawatts and maintained consistent operating conditions for the three day test period. The average coal firing rate was 310,500 lb/h (155 tph). This is typical operation for this unit.

2.1.2 - Coal Analyses

The literature suggests that coal composition can influence Hg speciation in the flue gas, with the chlorine concentration having an positive impact on the amount of oxidized Hg in the flue gas. The host site was firing an Illinois coal. Comprehensive coal analyses were completed on each of the daily test coal samples. Detailed results of the coal analyses for each test are presented in Table 22 and summarized in Table 3.

TABLE 3. SUMMARY OF DUCK CREEK COAL ANALYSIS
(Units are % dry basis unless noted)

	Test 1	Test 2	Test 3	Avg
Volatile Matter	42.16	42.31	42.48	42.32
Ash	10.08	10.02	9.82	9.97
Carbon	70.64	70.85	70.76	70.75
Hydrogen	4.85	4.77	4.68	4.77
Nitrogen	1.37	1.35	1.33	1.35
Oxygen	8.81	8.82	9.13	8.92
Total Sulfur	4.09	4.05	4.14	4.09
Chlorine	0.15	0.14	0.14	0.14
Fluorine, ppm	104	116	95	105
Mercury, ppm	0.070	0.081	0.096	0.082
Heating Value, Btu/lb	12748	12734	12777	12753

The Hg concentration in the coal ranged from 0.07 to 0.10 ppm ($\mu\text{g/g}$) on a whole coal basis. The uncertainty in the analytical method could account for the variability of the reported Hg concentrations. The averaged coal mercury concentration (0.082) was used for the material balance calculations and theoretical Hg input to the system. Assuming that all of the Hg in the coal volatilizes during combustion, the flue gas mercury concentration would be $\sim 8.4 \mu\text{g/m}^3$ (0.025 lb/h or 3.21 mg/sec). The chlorine content of this coal would result in a theoretical flue gas HCl concentration of ~ 100 ppmv. Actual measurements at the ESP inlet showed HCl concentrations between 60-70 ppmv. The fluorine concentration of this coal would result in a theoretical flue gas HF concentration of ~ 16 ppmv. The three flue gas HF measurements at the ESP inlet indicated HF concentrations of 9, 15, and 8 ppmv.

2.1.3 - Process Flow Rates

Coal Feed to Boiler. The only input stream required for the material balance calculation is the coal fed to the boiler. The coal firing rate was determined by two methods: the F-factor calculations and the volumetric feeders. The F-factor calculations are based on the measured flue gas flow rate, flue gas composition, and coal quality data to determine the coal feed rate. The accuracy of this method is a function of the accuracy of the measured parameters. The volumetric feeders give a direct readout of the volume of coal fed into the system, and the accuracy of this measurement is a function of the bulk coal properties and feeder calibrations. A comparison of the results of both methods showed differences of less than 4%. For this study, all results are based on the coal feed rate determined from the F-factor calculations.

Bottom Ash, Economizer Ash, and ESP Ash. The split between the bottom ash and the ESP ash was estimated after discussions with the plant operating staff and ultimately determined by forcing an ash material balance. The total ash was determined based on the coal firing rate and the ash content of the coal. The amount of ash entering the ESP was determined from the particulate matter collected using Ontario Hydro Hg Method. The particulate sample was obtained isokinetically using a representative duct traverse. The ash split was $\sim 60\%$ ESP ash;

the remaining 40% was split between the bottom and economizer ash. It was further assumed that 2% was economizer ash. These percentages conflict with plant and design estimates. Duck Creek personnel have traditionally used a 80:20 ratio for the fly ash/bottom ash split. This is probably a more reasonable estimate and for the purpose of this study, material balances were calculated using the plant partitioning factor and also the measured partitioning factor.

FGD Solids. The host site was not equipped with flow measuring device for this stream. The FGD solids production rate was estimated based on the FGD SO₂ removal rate, scrubber chemistry, and FGD solids analysis. The Duck Creek Station FGD system operates with natural oxidation. Based on this process, the FGD by-product material is CaSO₃ • ½H₂O. Analyses of collected samples indicate that this is the primary constituent. The data used in calculating the individual FGD production and Hg mass flow rates are summarized below.

TABLE 4. MASS FLOW RATE OF FGD SOLIDS

	Test 1	Test 2	Test 3
SO ₂ Produced, lb/hr	25,500	25,574	25,282
FGD SO ₂ Removal Eff, %	81.6	82.9	82.0
SO ₂ Removed, lb/h	20,806	21,199	20,718
SO ₂ Removed, lb-moles	325	331	324
Limestone Usage, ~lb/h	16.2	16.6	16.2
CaSO ₃ •½H ₂ O Produced, lb/moles	325	331	324
Mol. wt of CaSO ₃ •½H ₂ O	129	129	129
CaSO ₃ •½H ₂ O Produced, lb/h	41,937	42,730	41,760
ppm of Hg in FGD Solids, dry	0.42	0.25	0.30
lb/h of Hg in FGD Solids	0.018	0.011	0.013
mg/sec of Hg in FGD Solids	2.22	1.35	1.58

The FGD solid/sludge samples were analyzed. The data are presented in Table 26. The FGD slurry samples were obtained from the recycle line servicing each of the scrubber modules. The liquid portion was decanted from the solids and analyzed separately. No significant concentration of Hg was found in the decant water. The FGD solids were air-dried prior to analysis to reduce the potential for Hg losses through de-volatilization.

Limestone, Make-up Water to FGD, and FGD Slurry Filtrate. Analyses conducted on samples from these streams gave no indication of significant Hg contribution to the system. Because these streams do not contribute to the overall Hg balance, their mass flowrates are not required.

2.2 Description of Control Equipment

The primary control systems employed at Duck Creek Station are state-of-the-art low-NO_x burners for NO_x control, a three-field electrostatic precipitator (ESP) for particulate control, and a natural oxidation limestone FGD system for SO₂ control.

The low-NO_x burners are NO_x Core™ burners manufactured by Eagleair and were retrofitted in 1997 to comply with the Phase II NO_x emission standard of 0.45 lb/MM Btu. The ESP, also a Riley design, is part of the original construction (1976). The ESP is a cold-side precipitator with an effective ESP plate area of 442,400 ft². The unit is designed to meet the Federal particulate emissions standard of 0.1 lb/MM Btu. The design removal efficiency of this unit is 99.8% without the use of any conditioning agents. The scrubber is a venturi design manufactured by Riley and is part of the original construction (1976). The FGD system consists of four absorber modules, and the process is a natural-oxidation limestone FGD system. The SO₂ design removal efficiency is 86% while firing a 3.4% sulfur coal. The applicable Federal SO₂ emissions standard is 1.2 lb SO₂/MM Btu.

2.3 Flue Gas Sampling Locations

Speciated flue gas Hg samples (particulate, oxidized, and elemental) were obtained at: 1) the ESP inlet ducts, and 2) the FGD outlet duct. Gas phase measurements for HCl and HF also were obtained at these locations. Figure 2 is a schematic of the ESP inlet location and Figure 3 is a schematic of the FGD outlet location.

2.3.1 - ESP Inlet Duct (A-1)

The flue gas exits the economizer and splits into two identical ducts. After splitting, the gas is conveyed through parallel Lungstrom- type air pre-heaters. The air pre-heaters lower the flue gas temperature from ~700 °F to ~315 °F and heat the combustion air to the boiler. Flue gas then is conveyed from the exit of the air pre-heaters to the ESP through two ducts. Because of manpower constraints, the two ESP inlet ducts were sampled as a single duct. The individual duct dimensions are 33' wide by 12.5' deep (cross-sectional area of 825 ft²). The flue gas travels horizontally; the sampling ports are located on the top of the duct. This orientation requires a vertical traverse. Each duct was fitted with eight 3" diameter ports located on ~50" centers. Each port was equipped with a 75 lb pipe flange. The port length was 21". The combination of port length and duct depth required the use of a 16' probe. The Ontario Hydro Hg sampling was conducted using every other port (4 on each duct for a total of 8) with three traverse points for each port (the sampling locations are identified in Figure 2). The traverse grid comprised 24 sample points. Each point was sampled for 5 min resulting in a total sample time of 120 min. At the isokinetic sampling rate, sample volumes were 1.1 to 1.4 m³. Acid gas measurements were obtained at a single point as indicated in Figure 2. The sampling time ranged from 76 to 84 min (40 to 60 dscf).

2.3.2 - FGD Outlet Duct (A-2)

Flue gas exits the FGD through a single horizontal square duct that serves as a transition from the scrubber to the stack. The duct orientation and the location of the sampling points are presented in Figure 3. The duct dimensions at the sampling plane are 20' wide by 20' deep (cross-sectional area of 400 ft²). The duct is equipped with four sampling ports located on the top of the duct. A vertical traverse is required. The sampling ports consist of 4" diameter pipes, 12" in length, with a flange fitting, located on 5' centers. Volumetric gas flow measurements were conducted in this duct using a 20' pitot tube attached to an electric winch. There were five measurement points per port and twenty points per velocity traverse. Ontario Hydro Hg sampling was conducted isokinetically at a single point for a sampling duration of 110 to 135

min. The sample volume was between 2.4 and 2.8 m³. Gas phase HCl and HF sampling also was conducted at a single point for 80 to 97 min, resulting in sample volumes of 48 to 58 dscf.

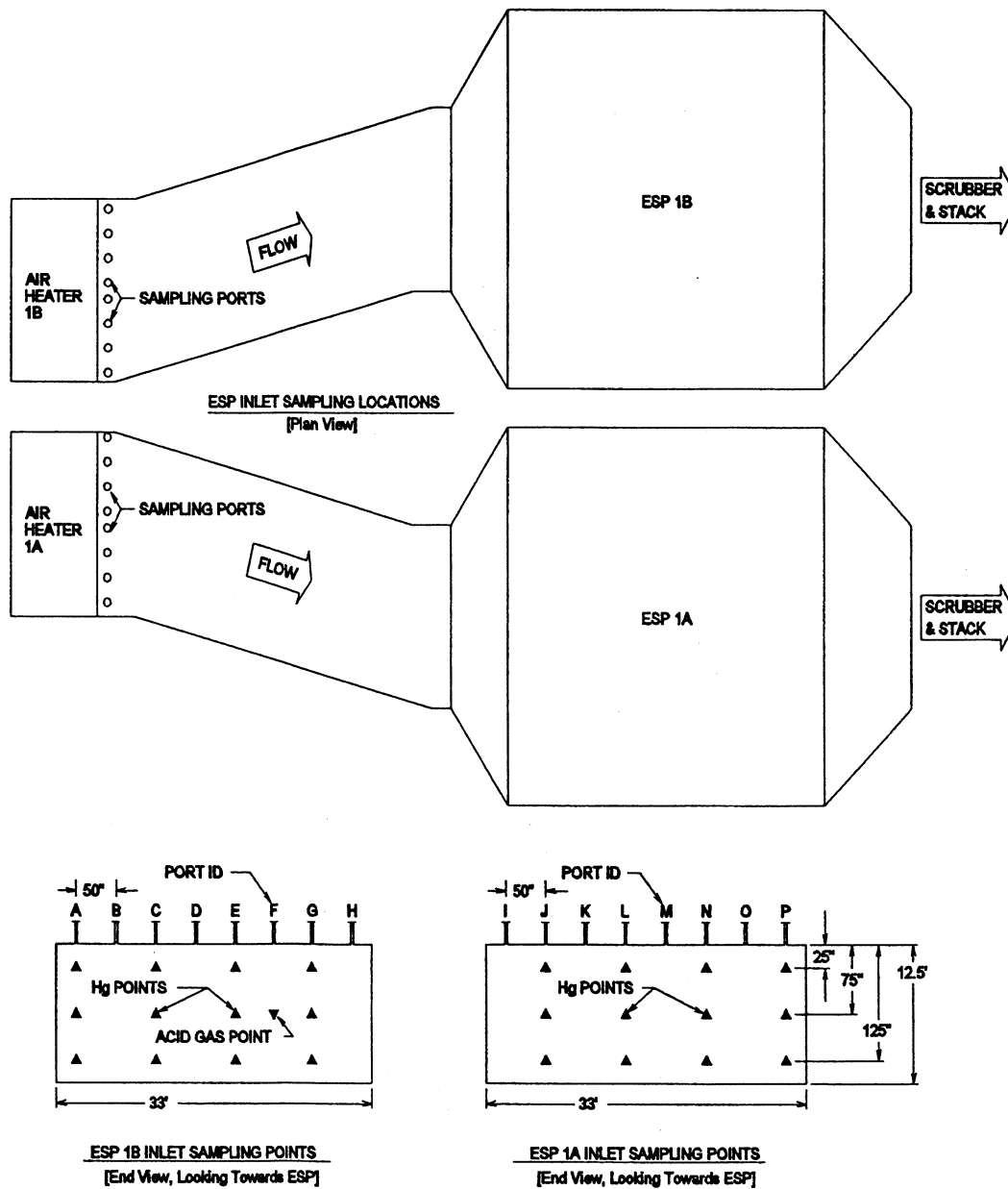


Figure 2. ESP Inlet Duct - Location and Sample Points

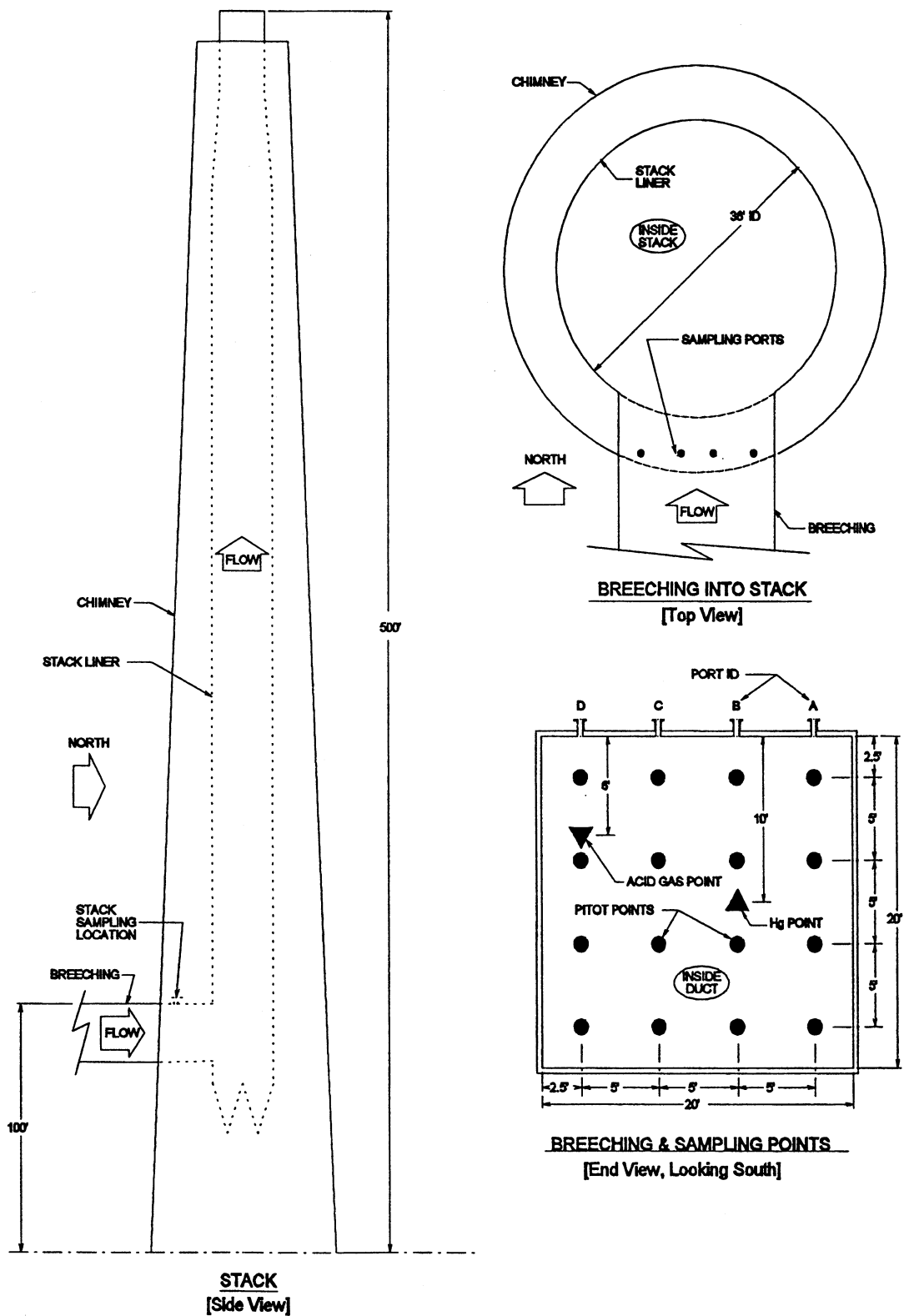


Figure 3. FGD Outlet Duct - Location and Sample Points

2.4 Process Stream Sampling Locations

The EPA Hg ICR field sampling protocol specified a representative coal sample be taken during each flue gas sampling period. The CONSOL sampling team augmented this sample with additional process stream samples required to determine the fate of Hg within the emission control system, Hg removal associated with the fly ash and with the FGD, and the data required to calculate Hg material balances. The additional samples included bottom ash, economizer ash, ESP hopper ash from each of the three precipitator fields, FGD slurry, limestone, and make-up water. The process stream sampling locations are presented in Figure 1 and the procedures used to obtain these samples are detailed as follows.

2.4.1- Coal to the Mills (S-1)

The Duck Creek Station is equipped with three double ended coal mills, each with two coal feeder. A representative coal sample was obtained for each test period from the coal transfer pipe feeding the A2 coal feeder. Samples were taken at regular intervals and composited for the duration of the flue gas sampling. The incremental coal samples were obtained with a custom-made chute that was placed in front of the rectangular access panel located on the side of the transfer pipe. When the panel was opened, coal would free-fall onto the chute and into our sample container. To ensure representativeness, sample increments were obtained every 30 to 40 min throughout the test program, with equal volumes taken each time. The increments were stored in 5 gallon plastic-lined buckets that were sealed to prevent moisture losses. The coal samples were transported to the CONSOL Laboratory located in Library, PA, for final sample preparation prior to analysis. ASTM preparation procedures were employed.

2.4.2 - Bottom Ash (S-2)

The Duck Creek Station is a dry-bottom boiler that employs a sluice system (water rinse out) to remove the accumulated ash that deposits in the bottom of the boiler (bottom ash). This removal is conducted once per shift. Daily arrangement were made with plant operators to conduct the removal prior to beginning the gas phase sampling. At the completion of the gas phase measurements, the plant sluiced the bottom ash. A grab bottom ash sample was obtained by opening the access door located near the bottom of the sluice tank (bottom of boiler) at the conclusion of the sluicing operation and filling a 5 gallon bucket of ash. This ash is representative of the ash that had accumulated over the test period. These samples were stored in air-tight 5 gallon plastic buckets prior to preparation and analysis. One sample was obtained for each test period.

2.4.3 - Economizer Ash (S-3)

The flue gas exiting the boiler passes through a bank of economizer tubes where additional heat transfer occurs. After passing through this component, the coarse fly ash particles are removed from the flue gas by a mechanical collector. The removed ash is collected in a row of hoppers referred to as economizer hoppers. The hoppers are emptied several times a day, and the ash is pneumatically transported to a storage silo prior to disposal.

The host station is equipped with eight economizer ash hoppers. Daily arrangement were made with plant operations to empty these hoppers before beginning sampling. At the

completion of the gas measurements, plant personnel collected a grab composite sample from these hoppers. This sample was obtained through an access pipe located near the bottom of each hopper using a sample thief. The composite samples were stored in glass bottles prior to preparation and analysis. These samples should be representative of the ash that had accumulated in the hoppers during the flue gas sampling. One composite sample was collected for each test period.

2.4.4, 5, 6 - ESP Hopper Ash (S-4, S-5, S-6)

Particulate removal is accomplished by a three-field (three deep, four wide), cold-side, electrostatic precipitator (ESP). The fly ash is collected in hoppers located below the ESP fields. There is a total of 24 ESP hoppers. As with the economizer ash, these hoppers are emptied several times a day and the ash is pneumatically transported to a storage silo prior to disposal. Daily arrangement were made with plant operations to empty these hoppers prior to the sampling activities. At the completion of our gas measurements, plant personnel collected an individual grab sample from one of the middle hoppers for each of the three fields (three ESP ash samples). These samples were obtained through an access panel located near the bottom of each hopper using a small sample scoop. The hopper samples were stored in glass bottles prior to preparation and analysis. These samples are representative of the ash that was collected by the individual ESP fields and had accumulated in the hoppers during the flue gas sampling period. One sample was collected from each of the three fields for each test period.

There is no accurate way of knowing the amount of ash collected in each field. For most typical ESP applications, the majority of ash (>85%) is collected in the first field with most of the remaining fly ash collected in the second field (10-15%). Very little ash is collected in the final field. For this reason, the analysis of the first field ash is most representative of the overall ash collected in the ESP.

2.4.7 - Limestone (S-7)

A limestone slurry is used to react with the SO₂. This slurry is prepared in the scrubber building by mixing pulverized limestone and make-up water. The host site used a single limestone supply source during this test period. For this reason, only a single grab sample was taken to represent the limestone quality for the three day test period. This sample was obtained from the limestone storage bin located in the mix room and was stored in an air-tight plastic bucket prior to preparation and analysis.

2.4.8 - Make-Up Water (L-1)

The host plant uses plant water as make-up water for the limestone slurry. One grab sample of make-up water was taken to represent the water quality for the three day test period. This sample was obtained from a tap located in the mix room and was stored in an acid-rinsed glass bottle prior to analysis. Nitric acid was used to preserve this sample.

2.4.9 - FGD Slurry Samples (L-2); FGD Filtrate (L-3) & FGD Solids (S-8)

The Duck Creek Station utilizes a venturi-type flue gas desulfurization (FGD) contactor for SO₂ control. This is an inhibited oxidation process where a slurry of precipitated SO₂ reaction product and limestone is circulated in a spray tower (module or train) to absorb SO₂ and convert it to a calcium sulfite/sulfate. The spent absorbing solution (limestone slurry) is collected in an effluent holding tank where it re-circulates to the spray tower. Suspended solids are removed from the holding tank through a sample bleed stream, and fresh limestone slurry is added to maintain the activity (as indicated by pH, 5.6 to 6.0 range) of the absorbing solution. FGD recirculating slurry samples were obtained from a sampling tap attached to the recirculating line. Slurry samples were collected twice during each test period (beginning and near the end of the gas sampling). The samples were collected directly into acid-washed glass bottles and composited to result in one sample per test period. This sample is representative of the scrubber product that coincides with the flue gas sampling.

The FGD slurry samples were filtered and the solids were air-dried (35°C for 24 hr) to minimize any loss of Hg. Mercury analysis was conducted on both the liquid filtrate (L-3) and the FGD solids (S-8).

3.0 SUMMARY AND DISCUSSION OF TEST RESULTS

3.1 Objectives And Test Matrix

The purpose of this test program was to document the Hg removal capability of the conventional ESP wet FGD emission control system while firing Illinois Basin coal. Specific test objectives were:

- (1) Measure the Hg speciation (particulate, oxidized, and elemental) in the flue gas at the ESP Inlet and FGD outlet.
- (2) Determine the Hg removal across the ESP and FGD systems.
- (3) Determine the fate of Hg within the entire utility system.
- (4) Measure the concentration of HCl and HF at the ESP Inlet and FGD Outlet.
- (5) Calculate Hg material balance closures as indicator of data quality.

The sampling matrix used to achieve these objectives is presented in the following tables.

TABLE 5. SAMPLE MATRIX FOR RUN 1 - JULY 14, 1998

Sample Type	Method	Location/Clock Time/Sampling Time		
		ESP Inlet	FGD Outlet	Process Stream
Speciated Hg	Ontario Hydro	1225-1520 (120)	1230-1445 (135)	
HCl & HF	Modified M-26	1335-1500 (84)	1336-1506 (90)	
Volumetric Flow	Method 2	With OH Sample	1700-1830 (90)	
Coal	Composite			1030-1545 (315)
Bottom Ash	Grab			1300-1400
Economizer Ash	Grab			1300-1400
ESP Ash - 1 st Field	Grab			1300-1400
ESP Ash - 2 nd Field	Grab			1300-1400
ESP Ash - 3 rd Field	Grab			1300-1400
FGD Slurry	Composite			1255 & 1510
Limestone	Grab			Sampled on 7/15
Make-Up Water	Grab			Sampled on 7/15

TABLE 6. SAMPLE MATRIX FOR RUN 2 - JULY 15, 1998

Sample Type	Method	Location / Clock Time / Sampling Time		
		ESP Inlet	FGD Outlet	Process Stream
Speciated Hg	Ontario Hydro	1000-1230 (120)	1033-1228 (115)	
HCl & HF	Modified M-26	1105-1231 (86)	1104-1234 (97)	
Volumetric Flow	Method 2	With OH Sample	1320-1420 (60)	
Coal	Composite			1015-1400 (225)
Bottom Ash	Grab			1300-1400
Economizer Ash	Grab			1300-1400
ESP Ash - 1 st Field	Grab			1300-1400
ESP Ash - 2 nd Field	Grab			1300-1400
ESP Ash - 3 rd Field	Grab			1300-1400
FGD Slurry	Composite			1132 & 1407
Limestone	Grab			1250
Make-Up Water	Grab			1146

TABLE 7. SAMPLE MATRIX FOR RUN 3 - JULY 16, 1998

Sample Type	Method	Location / Clock Time / Sampling Time		
		ESP Inlet	FGD Outlet	Process Stream
Speciated Hg	Ontario Hydro	0930-1150 (120)	0955-1145 (110)	
HCl & HF	Modified M-26	0953-1110 (76)	1021-1141 (80)	
Volumetric Flow	Method 2	With OH Sample	1240-1340 (60)	
Coal	Composite			0930-1315 (225)
Bottom Ash	Grab			1300-1400
Economizer Ash	Grab			1300-1400
ESP Ash - 1 st Field	Grab			1300-1400
ESP Ash - 2 nd Field	Grab			1300-1400
ESP Ash - 3 rd Field	Grab			1300-1400
FGD Slurry	Composite			1023 & 1321

3.2 Field Test Changes

No sampling problems occurred. However the pre-test survey identified a number of site-specific sampling problems that were addressed prior to the field sampling program. The CONSOL test team made a number of modifications to the Ontario Hydro sampling procedure to facilitate the sampling effort. Because the program was completed well in advance of the publication of the EPA ICR sampling protocol, strict adherence to this protocol could not be maintained. The sampling deviations incorporated into the CONSOL test program were discussed in a conference call among CONSOL, CILCO, and EPA personnel on April 15, 1999 and documented in a letter to William Grimley dated April 16, 1999. A copy of this letter and also the response from Bill Maxwell of the US EPA is included in Appendix G. A review, rationale, and suspected impact of these modifications are discussed as follows.

3.2.1 - FGD Outlet Sampling Location and Sampling Points

The scrubber outlet flue gas Hg concentration was determined in the horizontal breaching duct between the FGD outlet and the stack (see Figure 3). At this location, it was assumed that the gaseous species were well-mixed, and a single-point, isokinetic sample was used to obtain the flue gas Hg sample. This location is a rectangular duct, and velocity was determined using a multi-point traverse. Axial flow was confirmed at this location, and the velocity measurements are considered to be accurate and representative of the total volumetric gas flow. The Hg emission rate was calculated from the flue gas concentration and the flow rate data. Furthermore, this sample location is the "certified" sample location for meeting the 40CFR75 CEM requirements for SO₂, NO_x and flow.

Obtaining measurements in the stack was considered but dismissed due to the location of the sampling platform. The sampling platform is located at the 350' level. There is no access to this location other than a series of stairs and ladders. All sampling equipment would have had to be manually hoisted up the exterior of the stack. The stack is under positive pressure at this

location and there is sufficient flue gas leakage (~400 ppmv SO₂) to create a safety hazard. The test team would have had to have been trained in the use and operation of self contained breathing apparatus and safety procedures. Because of the lack of safe access to this location, the decision was made to use the alternate sampling location in the breaching duct.

The FGD outlet sampling location should have no effect on the flue gas Hg concentration or on the measured emission rate. The use of the alternative location resulted in minimal personal exposure to hazardous conditions.

3.2.2 - FGD Inlet Sampling Location and Sampling Points

The EPA sampling protocol prescribes sampling at the inlet of the FGD system for those utilities equipped with an FGD scrubber. The Duck Creek facility is not equipped with a sample platform or ports at this location. The FGD inlet duct is located in the scrubber building (positive pressure), which, at the sampling location, contains an elevated level of SO₂ in the ambient atmosphere. Similar safety concerns were identified at this location as were identified with the stack location. For Duck Creek Station sampling program, The ESP inlet ducts were used for the upstream FGD sample. Because of the possibility of Hg stratification at this location, a 24 point traverse, using eight sampling ports, was used.

The major disadvantage in using this location is the problem with the high particulate loading and the possible interaction between the gaseous Hg and the particulate matter on the filter. This condition was identified and corrected for by obtaining ESP ash hopper samples and measuring the Hg concentration on these samples. The ESP inlet gas train sample along with the ESP ash data were used to calculate the flue gas Hg concentration entering the FGD system.

The use of the ESP inlet location (see Figure 2) in lieu of the FGD inlet location for flue gas Hg measurements upstream of the FGD system provides a combined ESP-scrubber Hg removal. By determining the amount of Hg in the ESP ash and knowing the ash loading, it was possible to calculate the Hg removal across both the ESP and the scrubber.

3.2.3 - Use of Stainless Steel Nozzles

The Ontario Hydro method, as written by EERC personnel, specifies the use of a glass nozzle for the sampling train. While the use of inert material is certainly a prudent choice, it is not required for this measurement. In fact, EPA Methods 101 and 101A do not require glass nozzles. If there is concern about the effect of stainless steel on the gaseous Hg as it is conveyed through the sampling train, the same concern would apply to the interaction of gaseous Hg throughout the steel duct work and components (heat transfer surfaces, mechanical collectors, air preheater baskets, etc.) in the entire flue gas handling system.

Utility power systems contain harsh sampling environments that require robust sampling systems. For this test program, 20' and 15' sampling probes were used at ESP inlet and FGD outlet, respectively. The ESP inlet duct contained a series of 3" diameter pipe ports with a nipple offset of ~21". A similar condition was encountered at the FGD outlet. The use of stainless steel nozzles eliminated the very real concern of breakage during the insertion and

removal of the sampling probes. It is doubtful that testing of this nature can be economically conducted under these sampling constraints.

There is no evidence to suggest that stainless steel at the flue gas temperature of ~300°F has any impact on Hg speciation. A review of the nozzle and probe rinse solutions showed an insignificant amount of Hg in these rinses. The use of stainless steel nozzles facilitated the sampling in a time and cost-efficient manner.

3.2.4 - Use of a Stainless Steel Filter and Heated Teflon Transport Line at ESP Inlet

Sampling at the ESP inlet was further facilitated by using a 1.5" diameter stainless steel in-stack filter holder (fitted with a glass fiber thimble) that was attached to a 20' heated Teflon-lined probe. The probe was connected to the impinger box using a 20' heated Teflon line. This configuration is similar to that of a Method 17 sampling train and was used to accommodate the large duct depth (13' plus a 3' offset), small port diameter (~2.5"), and vertical probe orientation. Sampling was conducted through eight ports using a three-point traverse at each port.

Vertical orientation of the Ontario Hydro sampling train is difficult to achieve when traversing large ducts. By using an in-stack filter, the particulate matter can be immediately separated from the flue gas at stack temperature to reduce the potential for gas-to-particle interactions. The particulate-free flue gas sample then is conveyed through the heated Teflon probe liner and through the heated Teflon transfer line to the Ontario Hydro impinger box, with no loss of Hg or speciation changes. The Teflon components were thoroughly rinsed with both nitric acid and HCl to assure quantitative recovery of the Hg.

It is not suspected that the train configuration used at the inlet had any negative impact on the Hg measurements. The use of stainless steel components has already been discussed. The use of heated Teflon transfer lines that are rinsed after the sampling should be suitable for this application.

3.2.5 - Configuration of Impingers for Hg Speciation

CONSOL has been using the Ontario Hydro sampling train with two permanganate impingers, while the most recent EERC procedure calls for three. It is uncertain why EERC requires three permanganate impingers. U.S. EPA Method 29 employs two permanganate impingers for total Hg measurements. This train has been successfully used in a large number of combustion applications, including facilities burning waste materials where the flue gas Hg concentrations are orders of magnitude higher than those found in coal-fired combustion sources. CONSOL has completed more than 30 measurement programs in which material balances were determined for Hg. These were in the 80% to 120% closure range. There are no data to suggest that the two permanganate impingers are not collecting all of the elemental Hg in the flue gas. For these reasons, it is believed that this deviation had no impact on the resulting flue gas Hg measurements.

3.2.6 - Determination of Gas Composition by Electrochemical Analyzers

The gas composition data is required for the calculation of the molecular weight of the flue gas for use in the calculation of flue gas velocity and, ultimately, the volumetric flow rate. For this program, CONSOL utilized a portable electrochemical combustion gas analyzer (Teledyne Model Max 5) to determine the flue gas oxygen concentration at the exhaust of the meter box orifice. This instrument provides real-time oxygen concentrations, which are useful in identifying boiler/load changes and leaks in the sampling train. This instrument is extremely accurate for the oxygen concentrations found in coal combustion flue gas. The CO₂ concentration is calculated by knowing the O₂ concentration and the coal analysis. Eventually, these units may replace ORSAT analyzers.

3.2.7 - Additional Information Pertinent to the Hg Measurements

Coal samples were obtained for each test program. A complete suite of analyses (ultimate, proximate, major ash elements, Hg, and Cl) was conducted on each coal sample. Representative process stream samples of the ash streams also were obtained and analyzed for carbon, ash, and Hg. These samples included the bottom ash, economizer ash, and ESP hopper ash. Dedicated FGD slurry samples were collected for each flue gas test. These samples were filtered and the Hg concentration of both the filtrate and the filtered solids was determined. The analysis of the process stream samples provided the input for calculating Hg material balance closures, which for this test program, ranged from 90% to 110%.

The process stream data are useful in determining the fate of the collected Hg in the utility system. The material balance data add a degree of credibility to the FGD outlet Hg measurements and validate the reported Hg removal across the scrubber.

Gaseous HCl and HF concentration were measured in the flue gas at the ESP inlet and FGD outlet. Though not required by the EPA ICR, these data may provide some useful insight into Hg speciation and removal.

3.3 Presentation of Results

The primary use of this data is to determine the Hg speciation in the flue gas stream across the ESP-FGD system and to determine the Hg removal across this system. These results, and additional data useful in evaluating issues involving Hg speciation and removal, are discussed in this section. The basis for the Hg speciation, emission, and removal data are the three ESP inlet and FGD outlet paired Ontario Hydro train samples. The sampling conditions in effect while the Hg samples were obtained are summarized in Table 8.

**TABLE 8. SUMMARY OF FLUE GAS MEASUREMENTS OBTAINED
WITH THE ONTARIO HYDRO TRAIN**

Esp Inlet Measurement - 24 Point Sampling Traverse

	Test 1	Test 2	Test 3
Sample Time, min	120	120	120
Bar. Pres., inches of Hg	29.19	29.20	29.28
Static Pres., inches of H ₂ O	-9.95	-10.0	-10.0
% O ₂	3.9	3.8	4.2
% H ₂ O	11.1	11.7	11.3
Flue Gas Temp, °F	314	311	314
Gas Sample Volume, dry std cubic feet	52.75	42.98	44.04
Flue Gas Velocity, fps	30.9	24.82	25.96
Flue Gas Flow, actual cubic feet/min	1,531,400	1,228,800	1,285,300
Flue Gas Flow, dry std cubic feet/min	883,600	707,000	741,800
Particulate Rates:			
grains/dry standard cubic feet	2.84	2.87	2.53
lb/h	21,497	17,412	16,064
lb/MM Btu	5.41	4.33	4.12
% Isokinetic	101.8	103.7	101.3

FGD Outlet Measurement - Single Point Measurement

	Test 1	Test 2	Test 3
Sample Time, min	135	120	110
Bar. Pres., inches of Hg	29.19	29.20	29.28
Static Pres., inches of H ₂ O	-0.48	-0.29	-0.32
% O ₂	7.1	5.3	5.5
% H ₂ O	15.5	15.1	16.3
Flue Gas Temp, °F	133	133	133
Gas Sample Volume, dry std cubic feet	107.47	101.97	90.37
Flue Gas Velocity, fps	49.4	49.5	48.9
Flue Gas Flow, actual cubic feet/min	1,186,400	1,187,800	1,172,400
Flue Gas Flow, dry std cubic feet/min	869,600	875,300	853,400
Particulate Rates:			
grains/dry standard cubic feet	0.005	0.001	0.004
lb/h	41	9	27
lb/MM Btu	0.0103	0.0022	0.0069
% Isokinetic	99.5	103.7	100.6

The FGD outlet gas flow data reported in Table 8 was obtained by a full duct traverse using EPA Method 2. The flue gas volumetric flow rates determined from these measurements were 869,600, 875,300, and 853,400 dscfm for the three test periods. These values are representative of the flow rate and are used for the Hg emission calculations. The ESP particulate removal efficiency ranged between 99.81% to 99.95% and averaged 99.86%.

The ESP inlet location does not meet EPA criteria for Method 2 velocity measurements. Although single point velocities were determined in conjunction with the Ontario Hydro train sample, these data are most useful in assessing the isokinetic sampling accuracy. Volumetric

flow rate at this location for the three test periods is more accurately estimated from the measured flow rate at the FGD outlet and correcting the ESP inlet flow based on O₂ concentrations. The corrected volumetric flow rate for the ESP inlet duct and the adjusted particulate mass emission rates are presented below.

TABLE 9. ESP INLET VOLUMETRIC GAS FLOW RATES

	Test 1	Test 2	Test 3	Average
FGD Outlet Flow, dscfm	869,600	875,300	853,400	866,100
FGD Outlet Gas O ₂ , %	7.1	5.3	5.5	6.0
ESP Inlet Gas O ₂ , %	3.9	3.8	4.2	4.0
ESP Inlet Gas Flow, dscfm	705,900	798,500	787,000	763,800
Particulate Rate, lb/h	17,200	19,600	17,000	17,900

The calculated ESP inlet flow rates are used in the calculation of the Hg and particulate mass flow rate into the ESP.

3.3.1 - Hg Speciation Results

One set of simultaneous speciated Hg measurements were made at the ESP inlet and FGD outlet on July 14, 15, and 16, 1998. The results of this testing are presented in Table 10.

TABLE 10. Hg SPECIATION AT DUCK CREEK ESP INLET AND FGD OUTLET

	ESP Inlet	FGD Outlet		ESP Inlet	FGD Outlet
Particulate, µg/m³			Elemental, µg/m³		
Test 1	1.53	0.02	Test 1	2.22	1.58
Test 2	1.48	0.02	Test 2	1.02	1.55
Test 3	1.42	0.02	Test 3	1.40	1.87
Average	1.48	0.02	Average	1.55	1.66
Oxidized, µg/m³			Total, µg/m³		
Test 1	5.12	1.07	Test 1	8.87	2.67
Test 2	5.55	1.50	Test 2	8.05	3.07
Test 3	3.52	0.61	Test 3	6.35	2.50
Average	4.73	1.06	Average	7.76	2.75

The total Hg concentration determined with the Ontario Hydro train at the ESP inlet agree well with the theoretical Hg concentration calculated from the Hg in the coal and the amount of Hg on the bottom ash. Hg material balance closures at the ESP inlet were 92%, 96%, and 77%, and averaged 88%. The speciation breakdown at the ESP inlet was 20% particulate Hg, 60% oxidized Hg in the gas phase, and 20% elemental Hg in the gas phase (80% in gas phase). The concentration of Hg measured on the particulate matter collected in the sampling train is ~50% higher than the concentration of Hg measured in the ESP hopper ash. It is speculated that the sample train particulate is biased high (by 50%) as a result of absorption of gas phase Hg onto the sample train particulate during the sampling process. The FGD outlet speciation

showed an insignificant amount of Hg with the particulate catch ($0.02 \mu\text{g}/\text{m}^3$). $1.06 \mu\text{g}/\text{m}^3$ was measured as oxidized Hg, which is 40% of the gas phase Hg measured at this location. Assuming that the particulate fraction measured at the ESP inlet is oxidized Hg that was absorbed onto the fly ash, the average reduction for this Hg species is 80%. The gas phase elemental Hg fraction at the FGD outlet shows little change across the ESP and the scrubber and represents ~60% of the total Hg measured at this location.

3.3.2 - Hg Emissions

Mercury emissions are presented in Table 11.

TABLE 11. MERCURY EMISSION SUMMARY FOR THE DUCK CREEK STATION

	Test 1	Test 2	Test 3	Average
Hg Concentration in Stack Gas, $\mu\text{g}/\text{m}^3$	2.67	3.07	2.50	2.75 ± 0.29
Hg Emissions, lb/h	0.008	0.009	0.007	0.008 ± 0.001
Hg Emissions, mg/sec	1.02	1.18	0.94	1.05 ± 0.12
Energy Input to Boiler, MM Btu/h	3974	4021	3901	3965 ± 60
Hg Emission Factor, $\text{lb}/10^{12}$ Btu	2.01	2.24	1.79	2.02 ± 0.23
Hg Concentration in coal, $\text{lb}/10^{12}$ Btu (1)	6.43	6.43	6.43	6.43
Total Hg Removal Across Utility System, %	69	65	72	69 ± 4

The Hg concentration measured in the FGD (stack) outlet gas averaged $2.75 \pm 0.29 \mu\text{g}/\text{m}^3$. The Hg measurements were conducted with the plant operating near maximum capacity. Using the measured flue gas Hg concentration and the measured volumetric flow rate, the average Hg mass emission rate was 0.008 lb/h or 1.05 mg/sec. Using these data in conjunction with the coal feed rate and coal quality data, the average Hg emission factor is $2.02 \pm 0.23 \text{ lb}/10^{12}$ Btu. Provided the coal source is constant, the annual Hg emissions for this and other coal-fired utility systems would be a function of operating hours and operating load.

The uncontrolled Hg emission factor is $6.43 \text{ lb}/10^{12}$ Btu. This value was calculated using average coal quality data for both heating value and Hg concentration. Based on the uncontrolled Hg emission and controlled Hg emission factors, the total Hg removal across Duck Creek Station system (ESP and FGD) is 69%.

3.3.3 - Hg Removal with Ash Samples

The Hg removal due to adsorption on the ash samples was determined by calculating the Hg input to the boiler from the amount of Hg in the coal and the coal firing rate and comparing this input value with the amount of Hg found in the ash streams. Measurable amounts of Hg were

found in all of the ash streams. The Hg removals due to adsorption on the individual ash streams are shown as follows.

**TABLE 12. Hg REMOVAL WITH ASH SAMPLES
(using measured ESP particulate loading)**

	Test 1		Test 2		Test 3		Average	
Fly Ash Mass Flow	Measured (b)	Plant Est. (c)	Measured	Plant Est.	Measured	Plant Est.	Measured	Plant Est.
Coal Firing Rate, tph (a)	155.9	155.9	157.9	157.9	152.7	155.9	155.5	155.2
Hg Conc., ppm	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
Hg Mass Rate, mg/sec	3.22	3.22	3.26	3.26	3.15	3.15	3.21	3.21
Bottom Ash Rate, lb/h	13100	6840	12730	6714	14600	6855	13477	6803
Hg Conc., ppm	<0.01	<0.01	0.05	0.05	0.05	0.05	0.03	0.03
Hg Mass Rate, mg/sec	<0.02	<0.01	0.08	0.04	0.09	0.04	0.06	0.03
% Hg Removed	<0.6	<0.3	2.5	1.2	2.9	1.3	2.0	0.9
Econ. Ash Rate, lb/h	1200	1200	1200	1200	1200	1200	1200	1200
Hg Conc., ppm	0.03	0.03	0.06	0.06	0.04	0.04	0.04	0.04
Hg Mass Rate, mg/sec	<0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	<0.01
% Hg Removed	<0.3	<0.3	0.3	0.3	0.3	0.3	<0.3	<0.3
ESP Ash Rate, lb/h	19900	26160	19640	25656	19250	26219	19597	26012
Hg Conc., ppm (d)	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11
Hg Mass Rate, mg/sec	0.25	0.33	0.27	0.36	0.27	0.35	0.26	0.35
% Hg Removed	7.8	10.3	8.3	10.9	8.5	11.4	8.2	10.9
Σ Ash Rate, mg/sec	0.25	0.33	0.36	0.41	0.37	0.40	0.33	0.38
Σ % Hg Removed	7.8	10.3	11.0	12.6	11.7	12.7	10.2	11.9

a - Determined by F-factor Equation (flue gas flow rate & coal quality)

b - Ash flow rates calculated by using measured ESP Inlet PM rate and forcing an ash balance

c - Determined by plant estimate [20% bottom ash split, 1200 lb/h economizer ash and remainder as fly ash (~78%)]

d - Weighted average from samples collected from all three ESP fields

Using the measured ESP inlet fly ash rate and forcing an ash balance for the other ash streams, the bottom ash Hg removal was 1-3% , insignificant Hg removal was observed with the economizer ash, and the ESP ash removed 8% of the input Hg. The total Hg removal attributed to absorption on the ash samples ranged from 8% to 12% and averaged 10%. Using the plant estimate of 20% bottom ash results in a slightly higher Hg removal rate for the ESP of ~11%. In either case, the total Hg removal with the ash is 10% to 12%, with most of this occurring in the ESP.

The percent carbon in the bottom ash samples ranged from 9 to 19%. The percent carbon in the economizer ash samples ranged from 26-52%. The percent carbon in the ESP ash ranged from 1-10%. Even though the bottom and economizer ash samples contained more carbon than the ESP ash, there was little Hg absorption. The bottom and economizer ash samples are exposed to much higher temperatures than the ESP ash and the Hg absorbed onto the ash for these samples is affected mostly by the gas temperature, not the carbon concentration.

3.3.4 - Mercury Removal Across FGD System

The mercury removal across the FGD system is calculated from the FGD inlet and outlet gas phase Hg mass flow rates. The Hg mass flow rate at the FGD inlet was determined by two methods. The first method used a calculated flue gas Hg concentration at the FGD inlet based on the coal firing rate and Hg concentrations in the coal and the Hg removal due to adsorption on the ash samples upstream of the FGD system. The second method was based on actual gas phase Hg measurements at the ESP inlet, and assuming that the particulate Hg (as defined by then Ontario Hydro method) is collected in the ESP. These inlet Hg values were compared to the FGD outlet (stack) measurements to determine Hg removal. The results are presented in the following table.

TABLE 13. Hg REMOVAL ACROSS FGD USING CALCULATED FGD INLET VALUES

	Test 1	Test 2	Test 3	Average
Hg Mass Rate to Boiler, mg/sec	3.22	3.26	3.15	3.21
Hg Removed by Ash, mg/sec	0.25	0.36	0.37	0.33
Hg Mass Rate to FGD, mg/sec	2.97	2.90	2.78	2.88
FGD Outlet Hg Emission Data:				
Hg Conc., $\mu\text{g}/\text{m}^3$	2.67	3.07	2.50	2.75
Gas Flow, dscfm	869,600	875,300	853,400	864,800
Gas Flow, dscmm	24,627	24,789	24,168	24,528
Hg Mass Rate out of FGD, mg/sec	1.10	1.27	1.01	1.13
% Hg Removal Across FGD	63.0	56.2	63.7	60.8

TABLE 14. Hg REMOVAL ACROSS FGD USING ESP INLET ONTARIO HYDRO MEASUREMENTS

	Test 1	Test 2	Test 3	Test 4
ESP Inlet Duct:				
O ₂ Conc., %	3.9	3.8	4.2	4.0
Gas Phase Hg Conc., $\mu\text{g}/\text{m}^3$	7.34	6.57	4.92	6.28
Hg Conc. at 4% O ₂ , $\mu\text{g}/\text{m}^3$	7.30	6.49	4.98	6.28
FGD Outlet Duct:				
O ₂ Conc., %	7.1	5.3	5.5	6.0
Hg Conc., $\mu\text{g}/\text{m}^3$	2.67	3.07	2.50	2.75
Hg Conc. at 4% O ₂ , $\mu\text{g}/\text{m}^3$	3.27	3.33	2.74	3.11
% Hg Removal Across FGD	55.2	48.7	45.0	49.6

The mercury removals based on the ESP inlet Ontario Hydro data are biased low because of the interaction of gaseous Hg with the particulate solids collected by the filter assembly. The Hg concentration measured on the fly ash samples collected using the Ontario Hydro sample are ~0.20 ppm. This is twice that found in the ESP hopper ash. This indicates that ~½ of the Hg found in the Ontario Hydro filter solids is due to a gas phase interaction with the particulate. The equivalent gas phase Hg based on the mercury concentration on the fly ash sample averaged 1.48 µg/m³. Recalculating the gas phase Hg removal across the ESP using half of this amount results in an average Hg removal across the FGD of 56% which compares well with the value calculated from the process solid samples.

3.3.5 - Fate of Hg in Utility System and Material Balance Data

Two other objectives were to determine the fate of the removed Hg and to calculate Hg material balance closures to assess the quality of the measurements. Representative process stream samples to augment the flue gas measurements were obtained and analyzed to complete this task. The results of these measurements for are shown in Table 15. In this table the process stream ash flow rates were determined from the measured ESP fly ash and using this value to force an ash balance closure.

TABLE 15. FATE OF Hg AND MATERIAL BALANCES
(Hg mass flow units are mg/sec)

	Test 1	Test 2	Test 3	Average
Input Streams:				
Coal	3.22	3.26	3.15	3.21
Limestone	0.12	0.12	0.12	0.12
Make-up Water	0.00	0.00	0.00	0.00
Total Hg Input	3.34	3.38	3.27	3.33
Output Streams:				
Bottom Ash	0.02	0.08	0.09	0.06
Economizer Ash	0.00	0.01	0.01	0.01
ESP Ash	0.25	0.27	0.27	0.26
FGD Solids	2.22	1.35	1.58	1.71
FGD Filtrate	0.05	0.07	0.07	0.07
FGD Outlet	1.10	1.27	1.01	1.05
Total Outlet	3.64	3.05	3.03	3.24
% Hg Closure	109%	90%	93%	97%

The major mercury input was from the coal (>95%) with a small contribution from the limestone. The Hg found in the bottom ash samples accounted for ~2% of the total Hg; the Hg found in the economizer ash samples accounted for less than 0.5%. Hg reporting to the ESP ash represented ~8%. The Hg concentration of the FGD solids accounts for ~53% of the Hg originally present in the coal. The Hg present at the FGD outlet represents ~33% of the Hg in the coal. A small amount of Hg mercury was detected in the FGD filtrate water and

represents ~2% of the mercury. The Hg balance closures were between 90% and 109% and averaged 97%.

When recalculating the material balances using the plant estimate of a 20:80 ratio for the bottom ash/fly ash split, has a small impact on the balances. In this case, ~1% of the Hg reports to the bottom ash and ~10% reports to the ESP ash. The material balance closures for the three tests are 111%, 92%, and 94% for a grand average of 99%.

For this test program, a data quality objective of an average material balance closure of $\pm 20\%$ with no test greater than $\pm 30\%$ was set. These objectives were met.

3.3.6 - ESP Inlet and FGD Outlet Flue Gas HCl and HF Concentrations

The acid gas (HCl and HF) concentrations in the flue gas were determined at the ESP inlet and scrubber outlet (stack location) and removal rates were calculated from these measurements. The HCl removal rates are shown in the following tables.

TABLE 16. HCl EMISSIONS AND REMOVAL

	Test 1	Test 2	Test 3	Avg
% Cl in Coal	0.15	0.14	0.14	0.14
HCl Input, lb/h*	479	454	439	457
Flue Gas Measurements:				
ESP Inlet ppmv	72	61	65	66
ESP Inlet lb/h	322	276	288	295
FGD Outlet ppmv	3	2	2	2
lb/h	14	8	8	10
% HCl Removal	96	97	97	97

*Theoretical HCl input to boiler assuming all Cl in coal forms HCl upon combustion.

The HCl removal rate was 97%. Stack HCl emissions averaged 10 lb/hr. The HF removal data are shown in the following tables.

TABLE 17. HF EMISSIONS AND REMOVAL

	Test 1	Test 2	Test 3	Avg
ppm F in Coal	104	116	95	105
HF Input, lb/h*	34	39	31	35
Flue Gas Measurements:				
ESP Inlet ppmv	9	15	8	11
ESP Inlet lb/h	23	37	19	26
FGD Outlet ppmv	<0.4	<0.4	<0.4	<0.4
lb/h	<1	<1	<1	<1
% HF Removal	>95	>97	>95	>96

*Theoretical HF input to boiler assuming all F in coal forms HF upon combustion

The HF concentrations measured at the FGD outlet were below of method detection limits of 1 lb/hr. Using the method detection limits results in a minimum HF removal rate of 96%.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

4.1 Test Methods

4.1.1 - Speciated Hg Measurements

Speciated flue gas Hg measurements at the ESP inlet and FGD outlet were determined by the ASTM Draft *"Standard Test Method for Elemental, Oxidized, Particle-Bound, and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)."* This is an impinger-based method similar to EPA Method 5 and 29. Flue gas is isokinetically extracted through a nozzle and heated glass-lined probe. Particulate matter is removed by a heated quartz filter that is maintained at the duct temperature when practical and in the case of FGD outlet locations, 248 °F. Mercury analyses of the particulate solids result in the quantification of the Hg that is associated with the particles. The particulate-free gas then is conveyed through a series of chilled impingers containing different reagents; potassium chloride, a mixture of hydrogen peroxide and nitric acid, and acidified potassium permanganate. Potassium chloride serves to collect the oxidized Hg fraction. The peroxide impinger serves to oxidize any SO_x in the flue gas to preserve the strength of the permanganate solution. Any Hg collected in this impinger is assumed to be elemental. The potassium impingers collect the remainder of the elemental Hg. The flue gas then is conveyed through a silica gel impinger for moisture removal and then onto a standard Method 5 meter console.

CONSOL used this method at both the ESP inlet and FGD outlet incorporating some modifications to facilitate the sampling effort. Train schematics and sampling details are presented below.

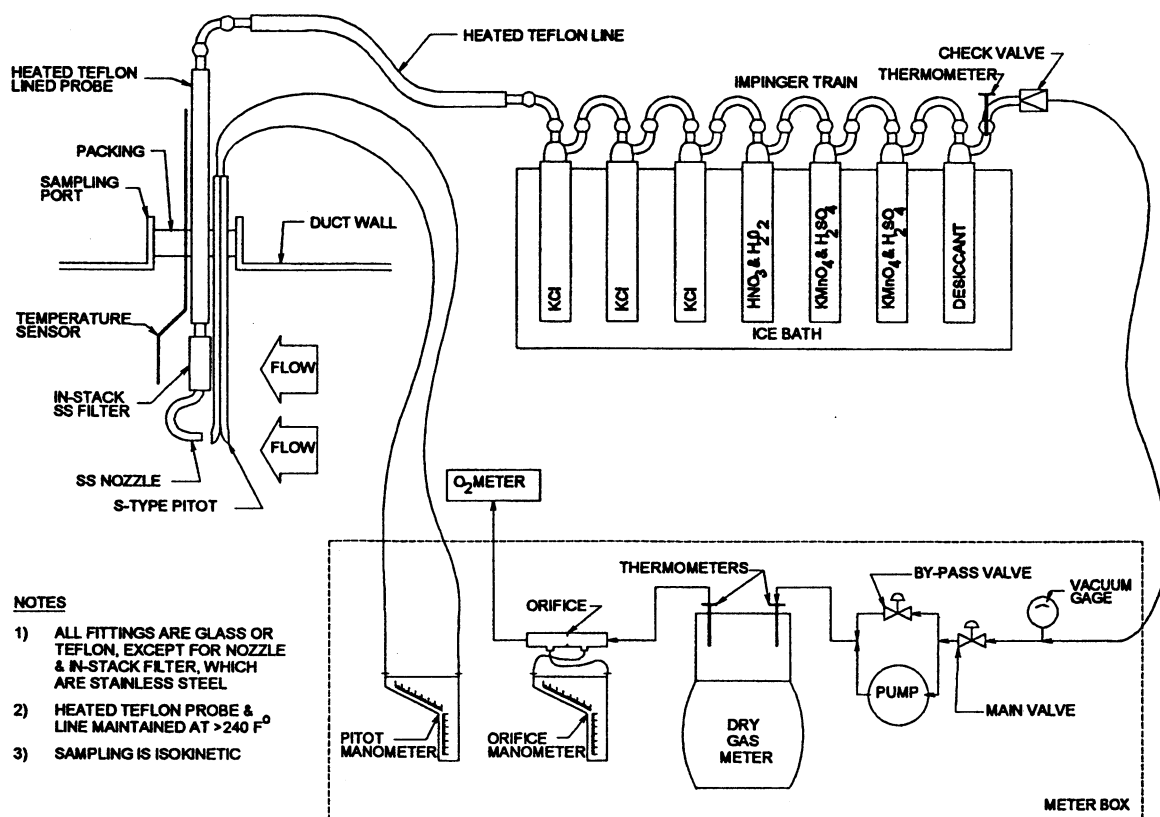


Figure 4. ESP Inlet Ontario Hydro Hg Speciation Train

An in-stack filter assembly was used at the ESP inlet. Particulate separation occurred at duct temperature (~300-330 °F). The rationale for this deviation was discussed previously. The heated Teflon-lined probe and heated Teflon transport line connecting the probe to the first KCl impinger were rinsed three times with a combination of hydrochloric and nitric acid to quantitatively recover any Hg that may have been deposited. These rinses were analyzed as "probe rinse" and are assumed to represent oxidized Hg. The interior surfaces of the stainless steel nozzle and filter canister were spray coated with Teflon to reduce the potential for Hg interactions.

Sampling was conducted over a 24-point grid. Velocity measurements were obtained with the attached pitot assembly for the determination of the isokinetic sampling rate, individual point velocities, and volumetric flow rate.

Gas composition was determined by an electrochemical analyzer connected to the orifice outlet as indicated in Figure 5.

A schematic of the Ontario Hydro train configuration used at the FGD outlet is shown below.

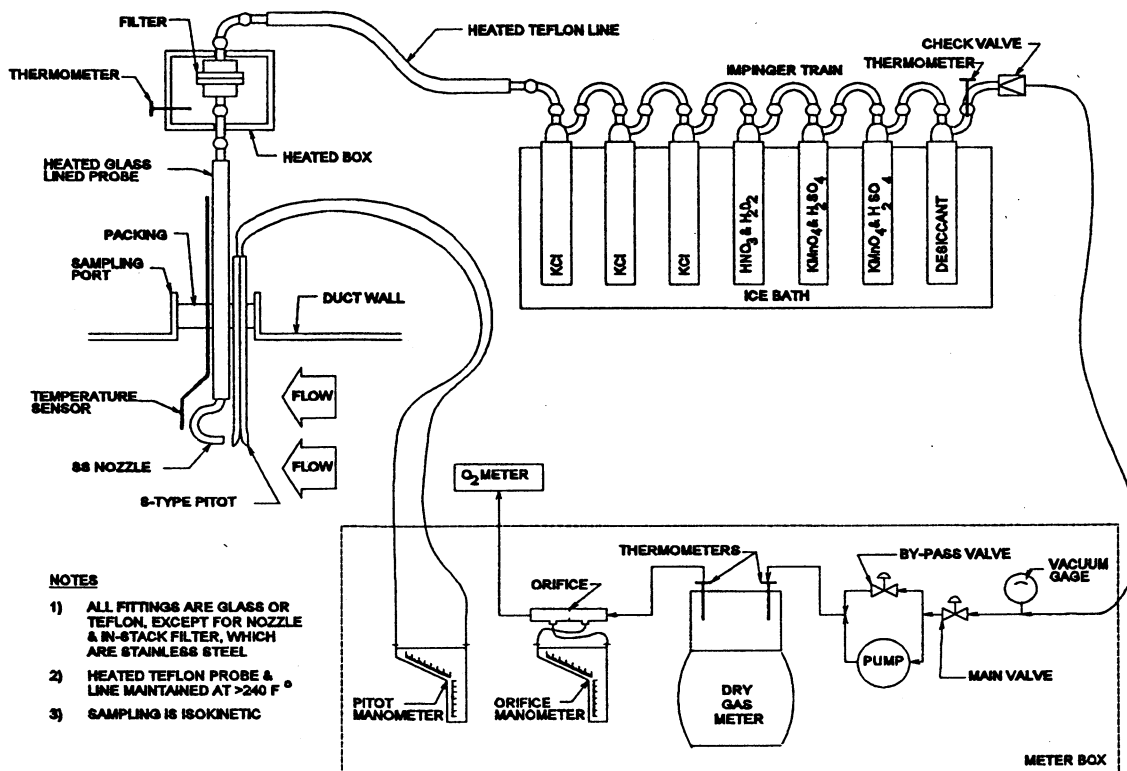


Figure 5. FGD Outlet Ontario Hydro Hg Speciation Train

As indicated in Figure 5, a short, heated Teflon transport line was used to connect the filter outlet to the first KCl impinger. This line was rinsed three times with a combination of hydrochloric and nitric acid. The rinse was added to the contents of the KCl impinger. The flue gas at this location is 100% saturated with water vapor at a temperature of $\sim 133^{\circ}\text{F}$. The probe, filter box, and heated Teflon line temperatures were maintained at $\sim 250^{\circ}\text{F}$.

Isokinetic sampling was conducted at a single point. It was assumed that sufficient gas mixing had occurred and the Hg in the flue gas was homogeneously dispersed. A separate 16-point velocity traverse was conducted using the procedures described in EPA Method 2.

Gas composition was determined by an electrochemical analyzer connected to the orifice outlet as indicated in Figures 4 and 5.

Figure 6 illustrates the sample recovery procedure used at the ESP inlet. An in-stack filter was used at the ESP inlet location. At the completion of the sampling, the filter assembly was detached from the probe. The assembly was held in an upright position, and the nozzle was gently tapped causing any residue solids to fall into the filter thimble. The filter thimble was

removed and placed in a glass bottle. The nozzle and the inside surface of the filter holder were rinsed with nitric acid, followed by hydrochloric acid, followed by de-ionized water. The Teflon probe liner and Teflon transport line were rinsed in the same manner. The rinses were combined into a common sample bottle identified as "probe rinse." The impinger train was transferred to the CONSOL mobile lab trailer for recovery. The U-tubes were disconnected and the liquid volumes in each of the impingers were measured. Acidified potassium permanganate was added in 1 mL volumes to the KCl impingers until the solutions were tinted purple. This step is required to preserve the collected Hg. The contents of the KCl impingers then were transferred to the KCl collection bottle. The impingers and connecting U-tubes were rinsed with nitric acid, followed by hydrochloric acid, followed by de-ionized water. The rinses were added to the KCl collection bottle, and the final sample volume was recorded. The nitric acid/peroxide impinger solution was transferred to the nitric/peroxide collection bottle. The impinger interior and inlet U-tube were rinsed with nitric acid, and these rinses were added to the collection bottle. The final solution volume was recorded. The permanganate impinger solutions were transferred to the permanganate collection bottle. The impingers and the connecting U-tubes were rinsed with nitric acid and these rinses were added to the collection bottle. Care was taken not to tighten the bottle cap since this solution is known to decompose and could pressurize the sample container. The final solution volume was recorded. Previous CONSOL experience has shown that, in some cases, the prescribed rinses do not quantitatively recover all of the Hg. For this reason, CONSOL incorporates strong acid rinses of all of the impinger glassware. These rinses are conducted with 8N HCl. All of these rinses are combined into a common collection vessel identified as the HCl rinse. The liquid volume of this sample is recorded.

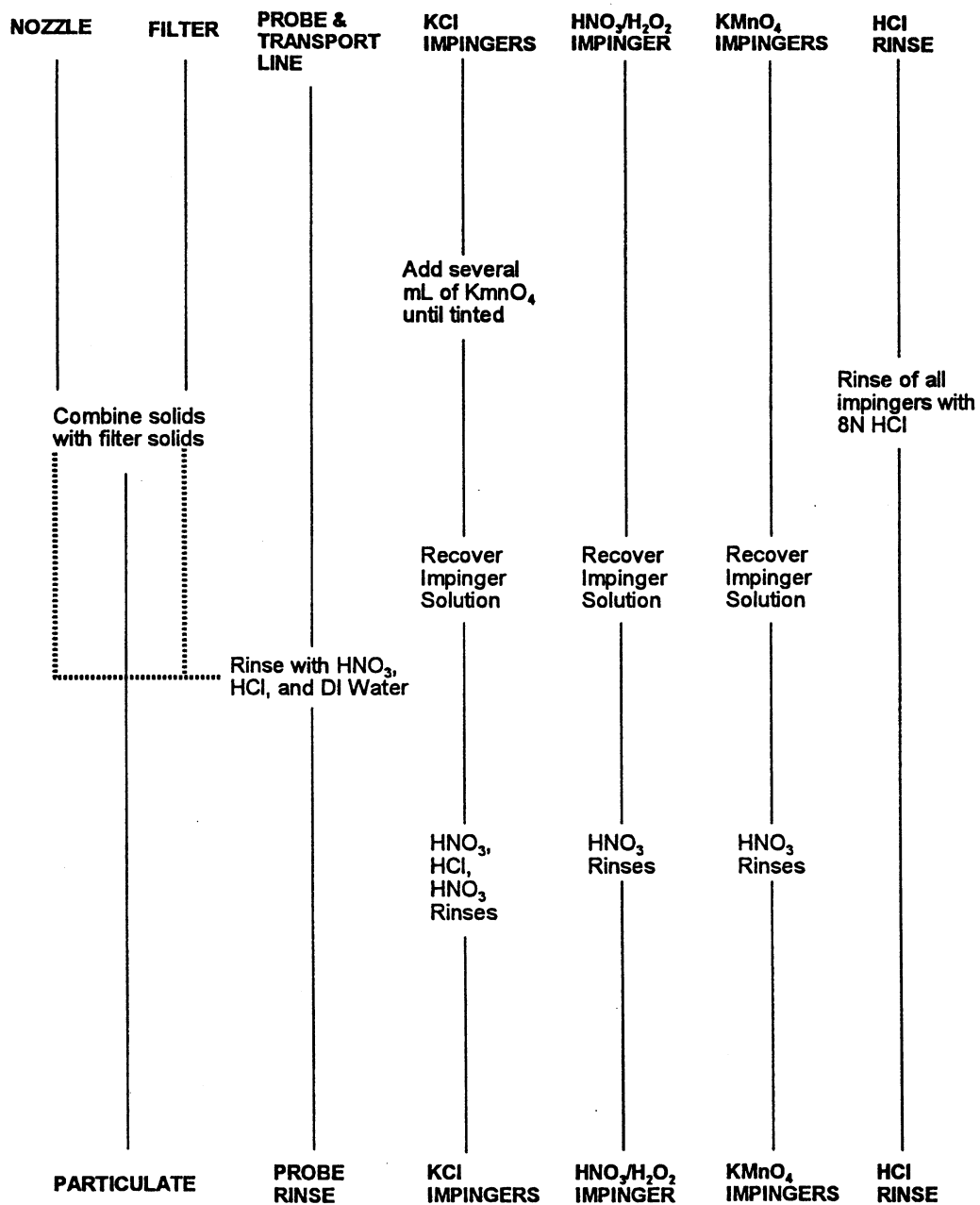


Figure 6. Ontario Hydro Hg Sampling Recovery Scheme Used at ESP Inlet Location

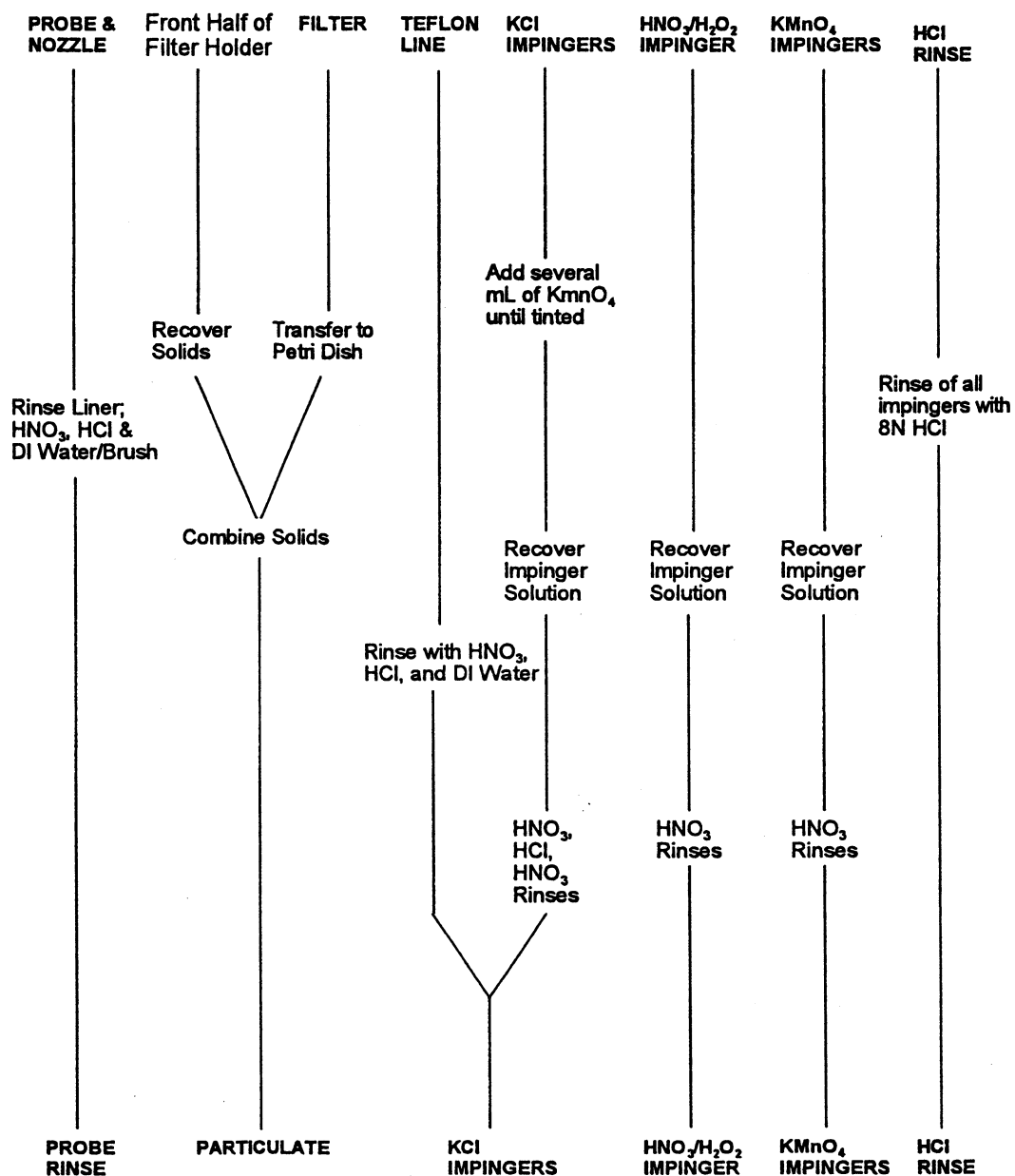


Figure 7. Ontario Hydro Hg Sampling Recovery Scheme used at FGD Outlet Location

Figure 7 illustrates the sample recovery procedure used at the FGD outlet. The conventional train configuration was used with the exception of the heated Teflon sample line connecting the filter outlet to the first KCl impinger. The recovery sequence for this sample was very similar to the ESP inlet sample and is detailed as follows.

After sampling, the probe and nozzle were rinsed with nitric acid, followed by hydrochloric acid, followed by de-ionized water. Three rinses were completed, followed by three passes with a nylon bristle brush. The liquids and residue particulate matter were collected in a sample bottle identified as the probe rinse. The sample volume was recorded. The filter was removed from the canister and placed in a Petri dish. Residue filter material and/or solids adhering to the front half of the cannister and the filter frit were brushed into the Petri dish. The interior surface of the filter assembly was rinsed with nitric acid, followed by hydrochloric acid, followed by de-ionized water. These rinses were added to the KCl impinger collection bottle. The Teflon transport line was rinsed with nitric acid, followed by hydrochloric acid, followed by de-ionized water. These rinses also were added to the KCl impinger collection bottle. The impinger assembly was recovered as described for the ESP inlet samples.

4.1.2 - Analysis of Ontario Hydro Hg Samples

The Ontario Hydro train samples (liquid impinger solutions and filter/filter solids) were analyzed by cold vapor atomic absorption (CVAA) following standard analytical procedures. Filter and filter solids were first digested in a mixture of HCl and HNO₃ in pressure vessels were maintained at 80 °C. After 60 min, additional volumes of HCl and KMnO₄ were added to the samples. A filtered aliquot was transferred to a sample vial to which hydroxyl amine/hydrogen sulfate was added. This vial was placed in the auto loader of a UNICAM Hg analyzer. The KCl, H₂O₂/HNO₃, and HCl rinse samples were analyzed in a similar manner. A liquid sample aliquot was transferred to a sample vial. Additional volumes of HCl and KMnO₄ were added to the sample. Finally, hydroxyl amine/hydrogen sulfate was added. This vial was placed in the auto loader of a UNICAM Hg analyzer. The KMnO₄ samples were prepared following the same procedure with the exception that no additional permanganate was added.

The CVAA analysis was conducted using a UNICAM Model 969 Hg analyzer. This instrument is equipped with an auto loader for unattended operation. In most cases, a separate analytical run was performed for each sample matrix. A typical analytical run consists of calibration standards, followed by QC checks for blank samples and standard reference samples. A duplicate analysis and spike recovery analysis were conducted on at least one sample from each solution matrix. The concentration of Hg in the solution samples was determined from the calibration curve and dilution ratios.

4.1.3 - Analysis of Coal and Ash Samples

The methods used for the analysis of the coal and ash samples are summarized in the following table.

TABLE 18. ANALYTICAL METHODS FOR PROCESS STREAM SAMPLES

Analyte	Coal	Comment
Moisture, Ash, Volatile Matter, and Fixed Carbon	ASTM D 5142-90	LECO Automated Thermo-Gravimetric
Carbon, Hydrogen, Nitrogen	ASTM D 5373	LECO Automated Combustion/ Thermo-Conductivity
Sulfur	ASTM D 4239-85	Automated LECO Combustion IR
Oxygen	By Difference	Calculated From Elemental Data
Higher Heating Value	ASTM D 1989-91	Parr Bomb Calorimeter
Mercury	ASTM D 6414	Pressure Digestion/CVAA
Chlorine	ASTM E 776, EPA Method 300	Bomb Digestion/Ion Chromatography
Major Ash Elements	ASTM D 3682-78	Acid Digestion/ICP-AES

5.0 QUALITY ASSURANCE SUMMARY

5.1 - Ontario Hydro Hg Measurements

This section provides detailed information regarding the QA/QC procedures associated with the speciated flue gas Hg sampling, analysis, and data reduction. Project data quality objectives as indicated by precision, accuracy, and completeness were evaluated. In addition, holding times, spike recoveries, laboratory blanks, calibrations, and sample handling are discussed.

5.1.1 - Flue Gas Measurements and Calculations

Field QA/QC activities associated for the speciated Hg measurements included pre- and post-test equipment calibrations, sampling conducted by trained field personnel following a standard sampling method, documentation of field data, sample train preparation, recovery, and preservation, and the collection of the appropriate sample blanks.

Copies of the field sampling sheets for the Hg measurements, acid gas measurements, and pitot traverse at the FGD outlet are included in Appendix A. These sheets were reviewed by the program manager at the conclusion of each test day to assure completeness. Isokinetic calculations were completed at the conclusion of each Hg sampling period to ensure accuracy. The stack sampling calculations were completed by computer spread sheets. Copies of these sheets and sample calculations are included in Appendix B. Field recovery sheets for the speciated Hg impingers and the laboratory reports for these samples are included in Appendix C.

The field sampling procedures included sampling at an acceptable isokinetic rate (100% \pm 10%) and verifying a final system leak rate of ≤ 0.02 CFM. These and other specific QC sampling parameters are shown in Table 19.

TABLE 19. FLUE GAS Hg SAMPLING FIELD QA/QC RESULTS

Test Location	Isokinetic Rate	Pre-Leak Check	Post-Leak Check	Gas Meter Calibration Values			
				Pre ΔH	Post ΔH	Pre Y	Post Y
Inlet 1	101.8	<0.02	<0.02	1.948	1.935	1.015	0.996
Inlet 2	103.7	<0.02	<0.02	1.948	1.935	1.015	0.996
Inlet 3	101.3	<0.02	<0.02	1.948	1.935	1.015	0.996
Outlet 1	99.5	<0.02	<0.02	1.844	1.933	1.000	0.973
Outlet 2	103.7	<0.02	<0.02	1.844	1.933	1.000	0.973
Outlet 3	100.6	<0.02	<0.02	1.944	1.933	1.000	0.973

As indicated by the data, the Hg samples were collected at acceptable isokinetic sampling conditions with no significant system leakage. The post-test calibration of the meter constants were within the $\pm 5\%$ allowable tolerance. Calibration data are included in Appendix D.

5.1.2 - Sample Chain of Custody

The impingers and filter assemblies were prepared by a senior technician. The filter cassettes and impinger boxes were labeled and additional documentation was recorded in a dedicated laboratory field notebook. At the completion of the sampling, the Ontario Hydro train components were recovered into pre-labeled sample bottles, with volumes and weights recorded on the field recovery sheets and in the lab notebook. At the completion of the test program, the samples were placed into storage boxes and cross-checked with the field recovery sheets. The samples were transported from Duck Creek Station to the CONSOL R&D laboratory using a company vehicle driven by the program manager. Upon arrival at the CONSOL lab, the sample boxes were transported to the CVAA lab, unpacked and sorted by test order and matrix. The samples were once again checked by the program manager for completeness and possible shipping damage. All samples were accounted for. Laboratory analytical request sheets were completed by the program manager. An example of these sheets is included in Appendix C. The analytical request sheets were submitted to the laboratory secretary who entered the samples and requests into our analytical data base. A computer program provided sample labels with sequential analytical numbers that were placed on the sample bottles. The samples were analyzed and the interim results were recorded on the original sample log-in sheets. These sheets were reviewed by a staff chemist and then passed to the lab secretary who inputted the interim results into our lab data base. Final analytical reports were computer generated from this data base. All of the lab reports for the samples collected and analyzed during this program are included in Appendix F. The samples were in the possession of CONSOL research employees during all phases of the program.

Sample storage prior to, during, and following the analyses was maintained in a secure laboratory that is accessible only by CONSOL personnel.

5.1.3 - Ontario Hydro Analysis QA/QC Results

The QA/QC procedures utilized for the CVAA analysis of the Ontario Hydro train samples included:

- Daily instrument set-up and 5-point calibration curve,
- Utilization of standard reference and blank samples,
- One replicate analysis for every matrix,
- One spike recovery for every matrix,
- Use of field blanks for each matrix, and
- Mercury material balance closures.

The mercury determinations of the Ontario Hydro train samples were completed over a three-day period using three CVAA instrument runs. A dedicated calibration curve was generated for each instrument run using five calibration standards consisting of 0.00, 1.00, 5.00, 10.0, and 20.0 ng/mL of Hg in solution. A linear relationship between the Hg concentration and the measured absorbance was observed for each calibration run as indicated in Figure 8.

Calibration was verified with QC check samples prepared from mercury in water standards supplied by the National Institute of Standards and Technology (NIST) and VHG Labs. The NIST sample is SRM 1641 C. The VHG Labs sample is product number PHGN-500. Certificates of analyses for both of these samples are included in Appendix D.

CVAA Calibration Curve

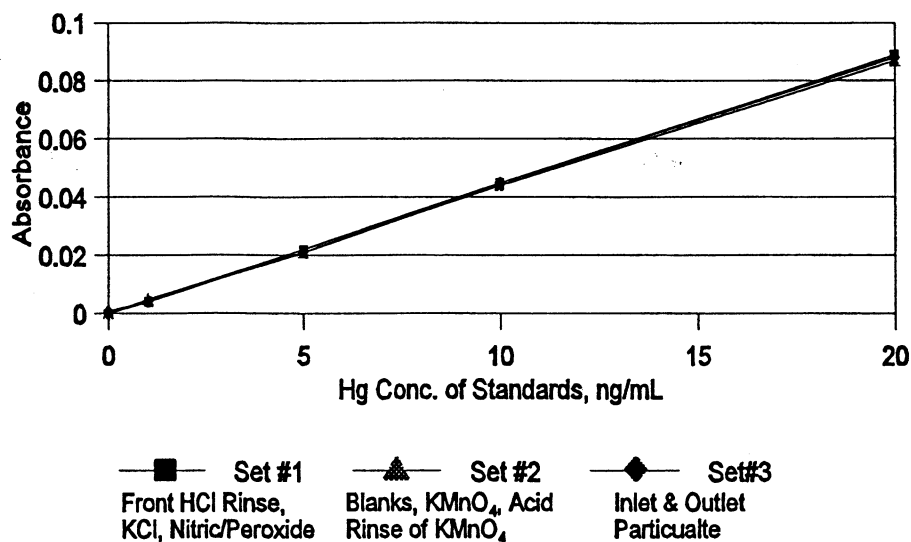


Figure 8. Calibration of UNICAM CVAA Analyzer for Hg Determination

The data in Figure 8 illustrate the consistent operation of the CVAA used for the Hg determinations.

Standard reference materials and lab blanks were analyzed in conjunction with the samples to assure both accuracy and to assess instrument drift. The results of these analysis are shown in the following table.

TABLE 20. RESULTS OF CVAA QC CHECK AND QC BLANK SAMPLES

	SRM 1641 C		10% HCl Blank
Number of QC Checks	10	Number of Blanks	12
Avg. Recovery, %	106.4	Average Hg Conc., ppb	0.07
Standard Deviation, %	7.1	Standard Deviation, ppb	0.10
Recovery Range, %	95 to 116	Blank Range, ppb	0.00 to 0.39

The average recovery for the ten QC check samples was 106%. The data quality objective of $100\% \pm 20\%$ was met. Similar data was obtained for the QC blank samples. The average blank value for the twelve QC blank samples was 0.07 ppb. The data quality objective of $0.00\% \pm 0.40\%$ was met. These data indicate the accuracy and precision of the CVAA analyzer used in the Ontario Hydro Hg determinations.

A known amount of Hg was added to selected samples for each solution matrix to determine spike recoveries. Failure to achieve a satisfactory spike recovery is usually indicative of a matrix interference and is useful tool in accessing data quality. The results of the spike recoveries for this program are summarized as follows:

TABLE 21. RESULTS OF 5 ppb Hg SPIKED SAMPLES

Sample Matrix	Measured Hg in Original Sample, ppb	Measured Hg in Spiked Sample, ppb	% Recovery
Probe HCl Rinse	0.00	5.20	104.0
KCl Impingers	0.00	5.19	103.8
H ₂ O ₂ /HNO ₃ Impingers	0.05	5.27	104.4
KMnO ₄ Impingers	1.63	6.85	104.4
Final HCl Rinse	0.00	5.39	107.8
Average			104.9%

The spike recoveries ranged from 104% to 108%. The data quality objective of 100% \pm 20% was met.

One field blank was recovered and analyzed with the actual flue gas samples. The average blank concentration for the solution matrices were:

HCl (probe and other rinses)	0.07 ppb
KCl Impingers	0.39 ppb
H ₂ O ₂ /HNO ₃ Impingers	0.00 ppb
KMnO ₄ Impingers	0.29 ppb

The Hg concentrations found in the blanks for the KCl and KMnO₄ impingers are equivalent to gas phase Hg concentrations of 0.10 and 0.05 $\mu\text{g}/\text{m}^3$ respectively. These concentrations are insignificant to the overall emissions reported. No blank corrections were incorporated into the emission calculation.

Process stream samples were collected to calculate mercury material balance closures for each test period. The Hg material balance closures, ranging from 90% to 109%, validate the FGD outlet Hg measurements.

A summary of the CVAA runs completed on the Ontario Hydro train samples is included in Appendix F.

100% sampling and analytical completeness was achieved for this test program.

5.2 Process Stream Samples

This section provides detailed information regarding the QA/QC activities associated with the process stream sampling, analysis, and data reduction. Project data quality objectives as indicated by precision, accuracy, and completeness were evaluated.

5.2.1 - Process Stream Sampling

Field QA/QC activities associated with the process stream samples included careful review of plant process cycles and sampling procedures, sampling conducted by trained field personnel following standard sampling methods, documentation for each process sample collected, and careful sample packing and transport. Copies of the field sampling sheets completed for each process stream sample are included in Appendix F.

5.2.2 - Sample Chain of Custody

All process stream samples were taken either by CONSOL personnel or by plant operators under the supervision of CONSOL personnel. Field sampling sheets were completed for each sample. The field samples were stored in pre-labeled containers. A visual inspection of the field sampling sheets and the collected samples was conducted by the program manager following each test period to ensure sample completeness and proper sample storage. The process stream samples were transported from Duck Creek Station to the CONSOL R&D laboratory using a company vehicle driven by the program manager. Upon arrival at the

CONSOL lab, the samples were transported to the sample preparation lab, unpacked, and sorted by test order and type. The samples were once again checked by the program manager for completeness and possible shipping damage. All samples were accounted for. Where required, sample preparation activities were initiated. Laboratory analytical request sheets were completed by the program manager. An example of these sheets is included in Appendix F. The analytical request sheets were submitted to the laboratory secretary who entered the samples and requests into our analytical database. A computer program provided sample labels with sequential analytical numbers, which were placed on the sample bottles. The samples were analyzed and the interim results were recorded on the original sample log-in sheets. These sheets were reviewed by a staff chemist, and then passed to the lab secretary who inputted the interim results into our lab data base. Final analytical reports are computer generated from this data base. All of the lab reports for the samples collected and analyzed during this program are included in Appendix F. The samples were in the possession of CONSOL research employees during all phases of the program. Sample storage prior to, during, and following the analyses was maintained in a secure laboratory that is accessible only by CONSOL personnel.

5.2.3 - Analytical Precision

All of the process stream samples were analyzed in duplicate. Analytical precision was determined by the percent relative difference (RPD) obtained in the duplicate analyses. ASTM criteria was met for all of the reported coal analysis. The RPD was 8.9% for the coal Hg analysis and 2.7% for the coal Cl analysis. A complete tabulation of the RPDs for the coal analysis are included in Appendix F.

5.2.4 - Analytical Accuracy

The CONSOL laboratory utilized a variety of Standard Reference Material (SRMs) and in-house standards in the process stream analysis. The analytical accuracy for ultimate, proximate, elemental, major ash elements, and higher heating value were 90% to 110%. The accuracy of the coal Hg analysis, as indicated from comparison of the digested solution with an SRM liquid sample, was 102%.

Three CVAA runs were conducted for the solid process stream (including the coals) obtained in this program. As with the Ontario Hydro train samples, a perfect linear relationship was observed between the Hg concentration in solution and absorption for each of the three calibration runs. Ten QC checks (prepared from SRM 1641 C) ranging from 7.35 ppb to 20.0 ppb Hg-in-solution were analyzed during the solid analysis. The percent recovery ranged from 96% to 107% and averaged 102% (std. dev.= 4%). Nine QC blanks were analyzed with the average blank concentration of 0.06 ± 0.08 ppb.

TABLE 22. ANALYSIS OF DUCK CREEK STATION TEST COALS
(all values reported on a percent dry basis, unless otherwise noted)

Test ID	1	2	3	Avg	Standard Deviation	% Relative Standard Deviation
Date	7/14/98	7/15/98	7/16/98			
Analytical No.	984110	984111	984112			
Total Moisture	17.40	17.09	16.77	17.09	0.31	1.8%
Volatile Matter	42.16	42.31	42.48	42.32	0.16	0.4%
Ash	10.08	10.02	9.82	9.97	0.14	1.4%
Carbon	70.64	70.85	70.76	70.75	0.10	0.1%
Hydrogen	4.85	4.77	4.68	4.77	0.08	1.8%
Nitrogen	1.37	1.35	1.33	1.35	0.02	1.5%
Oxygen	8.81	8.82	9.13	8.92	0.18	2.0%
Sulfur	4.09	4.05	4.14	4.09	0.04	1.1%
Chlorine	0.15	0.14	0.14	0.14	0.01	4.0%
Fluorine, ppm	104	116	95	105	10	10.0%
Hg, ppm	0.070	0.081	0.096	0.082	0.013	15.9%
Heating Value, Btu/lb	12748	12734	12777	12753	22	0.2%
Major Ash Elements: (Ignited at 750 °C)						
SiO ₂	48.07	48.87	48.58	48.51	0.40	1%
Al ₂ O ₃	17.75	17.79	17.35	17.63	0.24	1%
TiO ₂	0.87	0.89	0.88	0.88	0.01	1%
Fe ₂ O ₃	18.31	18.47	18.45	18.41	0.09	1%
CaO	4.77	4.95	4.43	4.72	0.26	6%
MgO	0.84	0.88	0.85	0.86	0.02	2%
Na ₂ O	1.23	1.24	1.17	1.21	0.04	3%
K ₂ O	2.18	2.08	2.06	2.11	0.06	3%
P ₂ O ₅	0.12	0.15	0.15	0.14	0.02	12%
SO ₃	3.58	3.63	3.69	3.63	0.05	2%
Undetermined	2.28	1.05	2.39	1.91	0.74	39%

TABLE 23. ANALYSIS OF DUCK CREEK BOTTOM ASH SAMPLES
(all values reported on a percent dry basis, unless otherwise noted)

Test ID	1	2	3	Avg	Standard Deviation	% Relative Standard Deviation
Date	7/14/98	7/15/98	7/16/98			
Analytical No.	984107	984108	984109			
Total Moisture	2.15	1.18	1.74	1.69	0.49	29%
Ash	89.20	92.73	78.48	86.80	7.39	9%
Carbon	9.39	6.76	19.31	11.82	6.59	56%
Sulfur	0.58	0.31	0.85	0.58	0.27	46%
Hg. ppm	<0.01	0.05	0.05	0.04	0.03	75%

TABLE 24. ANALYSIS OF DUCK CREEK ECONOMIZER ASH SAMPLES
(all values reported on a percent dry basis, unless otherwise noted)

Test ID	1	2	3	Avg	Standard Deviation	% Relative Standard Deviation
Date	7/14/98	7/15/98	7/16/98			
Analytical No.	984104	984105	984106			
Total Moisture	0.45	0.53	3.19	1.39	1.55	112%
Ash	73.45	70.74	45.14	63.11	15.56	25%
Carbon	25.80	27.89	51.50	35.06	14.22	41%
Sulfur	1.13	1.32	1.90	1.45	0.40	28%
Hg. ppm	0.03	0.06	0.04	0.04	0.02	35%

TABLE 25. ANALYSIS OF DUCK CREEK ESP ASH SAMPLES
(all values reported on a percent dry basis, unless otherwise noted)

Hopper 1 - Front

Test ID	1	2	3	Avg	Standard Deviation	% Relative Standard Deviation
Date	7/14/98	7/15/98	7/16/98			
Analytical No.	984100	984097	984094			
Total Moisture	0.46	1.10	0.96	0.84	0.34	40%
Ash	94.91	97.11	96.43	96.15	1.12	1%
Carbon	3.61	0.87	1.11	1.86	1.51	81%
Hg, ppm	0.11	0.10	1.11	0.11	0.01	5%

Hopper 5 - Middle

Analytical No.	984101	984098	984095	Avg	SDEV	PRSD
Total Moisture	0.32	0.37	0.20	0.30	0.09	29%
Ash	93.46	96.20	96.76	95.47	1.76	2%
Carbon	4.66	3.04	2.57	3.42	1.09	32%
Hg, ppm	0.11	0.14	0.15	0.13	0.02	16%

Hopper #9 - Back

Analytical No.	984102	984099	984098	Avg	SDEV	PRSD
Total Moisture	0.29	0.26	0.22	0.26	0.03	14%
Ash	95.72	97.07	87.12	93.29	1.68	6%
Carbon	3.09	2.53	10.93	5.52	1.37	38%
Hg, ppm	0.08	0.10	0.07	0.08	0.02	18%

Weighted Average Values for Composite ESP Hopper Ash

Test ID	1	2	3	Avg	SDEV	PRSD
Ash	94.70	96.78	93.44	94.97	1.68	2%
Carbon	3.79	2.15	4.87	3.60	1.37	38%
Hg, ppm	0.10	0.11	0.11	0.11	0.01	6%

TABLE 26. ANALYSIS OF DUCK CREEK FGD SOLIDS SAMPLES
(all values reported on a percent dry basis, unless otherwise noted)

Test ID	1	2	3	Avg	Standard Deviation	% Relative Standard Deviation
Date	7/14/98	7/15/98	7/16/98			
Analytical No.	984091	984092	984093			
Total Moisture	0.42	0.31	0.21	0.31	0.10	33%
Ash	95.29	95.12	95.44	95.28	0.16	<1%
Sulfur	19.94	19.83	20.80	20.19	0.53	3%
Hg, ppm	0.97	0.66	0.50	0.71	0.24	34%
Major Ash Elements: (whole sample basis)						
SiO ₂	0.71	0.56	0.42	0.56	0.14	26%
Al ₂ O ₃	0.17	0.17	0.20	0.18	0.02	10%
TiO ₂	0.01	0.02	0.01	0.01	0.00	0%
Fe ₂ O ₃	0.23	0.23	0.21	0.22	0.01	5%
CaO	42.64	42.06	42.32	42.32	0.29	1%
MgO	0.44	0.33	0.19	0.32	0.12	39%
Na ₂ O	0.05	0.05	0.05	0.05	0.00	0%
K ₂ O	0.06	0.06	0.05	0.06	0.01	10%
P ₂ O ₅	0.03	0.03	0.02	0.03	0.01	33%
SO ₃	53.76	53.52	54.61	53.96	0.57	1%
Undetermined	1.90	2.97	1.82	2.26	0.61	27%

TABLE 27. ANALYSIS OF DUCK CREEK COMPOSITE LIMESTONE SAMPLE
(all values reported on a percent dry basis, unless otherwise noted)

Test Site	Duck Creek Station
Date	7/14/98 to 7/16/98
Analytical No.	984103
Total Moisture	0.07
Ash	56.72
Carbon	11.68
Sulfur	0.04
Hg, ppm	<0.03
Major Ash Elements: (whole sample basis)	
SiO ₂	0.72
Al ₂ O ₃	0.11
TiO ₂	0.01
Fe ₂ O ₃	<0.01
CaO	55.73
MgO	0.49
Na ₂ O	<0.01
K ₂ O	0.04
P ₂ O ₅	0.06
SO ₃	0.30
Undetermined	42.54

**TABLE 28. Hg CONCENTRATION OF ONTARIO HYDRO
SAMPLING TRAIN FILTER SOLIDS**

Test ID	1	2	3	Avg	SDEV	PRSD
Date	7/14/986/2	7/15/986/	7/16/986			
ESP Inlet Filter, ppm	0.22	0.21	0.23	0.22	0.01	5%
FGD Outlet Filter, ppm	1.8	5.5	1.7	3.0	2.2	72%